

AN APPRAISAL OF THE PRODUCTION AND UTILITY OF
DIGITAL ATLASES IN AFRICA: A CASE STUDY OF
SWAZILAND

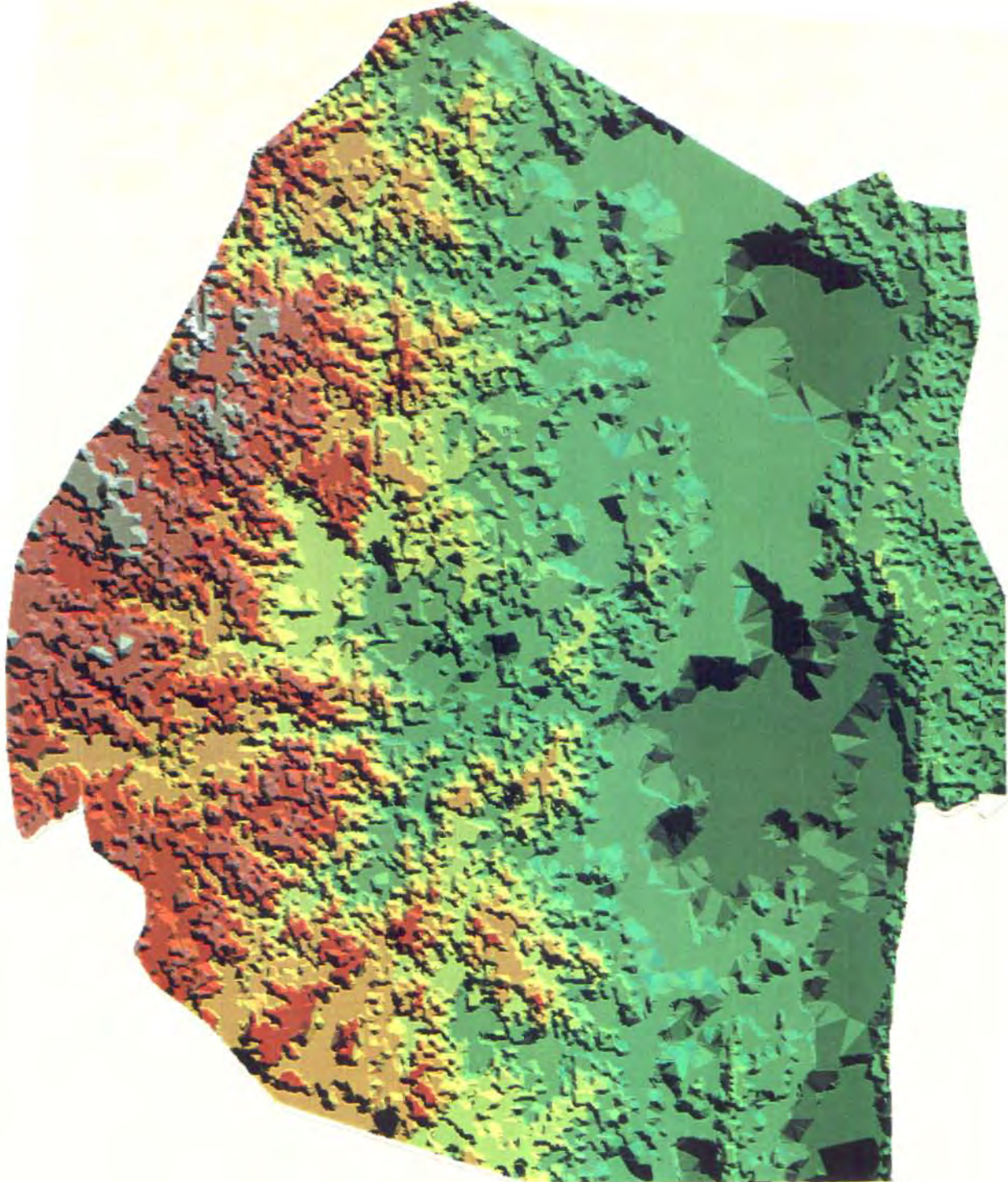
A thesis submitted in fulfilment of the
requirements for the degree of

MASTER OF SCIENCE
of
RHODES UNIVERSITY

by

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February 1999



Swaziland in relief

Abstract

This research will appraise the production and utility of digital atlases in an African context, using personal experience gained through the production of a digital atlas for Swaziland, the opinions obtained from other producers of African digital atlases and relevant literature.

Since the 1950s, decision makers and researchers have viewed information as a powerful contributor to national development. Over the past thirty years, developed countries have increased the efficient collation and dissemination of geographic information through the utilization of the digital environment. The development of Geographic Information Systems (GIS) has increased the range of applications attainable in digital mapping projects. Applications have ranged from resource inventories to the monitoring of environmental degradation, crime patterns and service provision.

The patchy history of data collection, analysis and mapping in Africa, has had a limiting effect on the ability of countries to identify, plan and control their resources efficiently. Despite the desire to automate the mapping process and reap some of the planning benefits evident in the developed world, Africa has not succeeded in mobilising full technological potential. Political instability, poor infrastructure, the absence of national policy guidelines, and a lack of skilled manpower are some of the issues which have limited utilization. Despite many of the hurdles faced by African countries, automated mapping and analysis technologies are still being pursued.

The role of computers in the utilisation of data has become apparent through several means, one of which is the digital atlas. Analytical functions in many of these products allow situation modelling and provide superior graphic displays in comparison to their paper counterparts. Several African countries have embarked on the development of national digital databases and in some cases have produced digital national atlases. The potential to improve resource utilization, service provision and land use planning using these atlases, does exist. The production and utility of these atlases in an African context, however, needs closer assessment. "Computers don't clothe, don't cure, don't feed. Their power begins and ends with information. Their usefulness is therefore strictly linked to the effectiveness of the information" (Gardner, 1993:16).

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Acknowledgements

Many thanks to Professor Roddy Fox for his encouragement and guidance throughout this research. I would like to extend my gratitude to the staff and students of the Geography department who made the process run that much more smoothly.

Mr Hubbard, from the Rhodes printing department for his patience whilst I was printing the maps.
To Billy Morgan of the Computer Science department for assisting me in the writing of the CD-ROMs.

To all the individuals who gave up their time for interviews. Thank you to Mike Shand and Erik Van Waveren for their continuous input and support.

Many thanks to Fergus for helping out during the entire research period and particularly during the printing process!

And finally to my parents and my sister for their support, without which this research would not have been possible.

Chapter One: Introduction

"GIS, geographical information systems research, is the hottest thing in geography and map making these days...and the power of GIS has really nothing to do with simply translating paper maps into video screen pictures. It is the prospect of combining map images with other kinds of information - pictures from satellites, statistics from census data - to be able to display relationships graphically that were impossible before the computer" (Huxhold,1991:xiii)

1.1 Introduction

This introduction consists of four sections. The reader will be introduced to the use of information technology in the developed and developing worlds. This will be followed by a brief overview of conventional mapping in Africa. An introduction to the concept of digital atlases will be supported by an outline of the characteristics associated with them. The remainder of the chapter provides the context for the research, an outline of digital mapping activity in Swaziland is given as well as a description of the study area. The aim, objectives and methods of the research are then stated.

1.1.2 Information technology in the developed and developing worlds

The developed world has consistently maintained its position at the forefront of computer technology development. Developed countries have not only had access to state of the art machines and skilled personnel, but have also had the funds to develop, acquire and run such systems. The benefits of computerised data have been reaped in these countries over the past 30 years. In the 1960s, Canada became concerned over the use of its natural resources. The government set out to produce a country wide land use inventory. Information relating to the capability of the land to sustain forestry, wildlife, agriculture and recreation was gathered with the aim of helping the government make more informed land use decisions (Tomlinson,1984). This was one of the first instances in which computers were used to manage extensive amounts of data. Technicians searched for ways to input graphic map data along with vast amounts of related attribute information into computers. It was at this time that the first geographic information system was developed.

Looking back at the 1970s, Larsson (1991) notes that it was at this time that many western governments followed Canada in the realisation that land was a valuable resource and would require effective management systems. Tomlinson (1984:22) notes that governments "perceived the need not only to gather but also to handle and analyse geographical data and to do so in a timely manner". GIS not only provided the means of achieving efficiency as a tool for data collection, storage and manipulation but enabled the presentation of statistical analysis through the use of cartographic display capabilities.

Keates (1989:284) suggests that the "desire to output maps more quickly...analyse and process large quantities of statistical data...and indeed to produce many different versions with facility" has been the driving force behind increasing digital mapping activity. Shand and Silayo (1996) note that since 1989, there has been a significant increase in the utilisation of digital mapping systems and techniques for the production of maps and atlases by the mapping industry worldwide. Governments of the developing world are now realising their need to gather, update, manipulate, analyse and map large amounts of data and are embarking on the path of digital automation, travelled by the developed world over thirty years ago.

In China the importance of the economic role of rural areas has spurred the production of digital maps and atlases for continued agricultural regional planning (Taylor, 1985). China has a digital database of all 2300 counties, and this forms part of the digital Population Atlas of the People's Republic of China. Taylor (1985) notes that the same database has been used to produce an Atlas of Local Diseases. The result is a vast amount of spatially referenced data which is potentially available for efficient dissemination to a wide user base; both public and private.

Data collection, analysis and mapping has a patchy history in Africa. It goes without saying that any nation's ability to identify, plan and control the use of its resources has a direct effect on its development. According to Chukwudebe and Duru (1985) notoriously weak application of cartographic knowledge in the development and planning processes is suggested to be the cause of the many examples of regional economic and development differences, the lack of urban control and infrastructural disorderliness on the continent. Adenyini (1985) notes that one of the main problems facing countries in Africa, is their limited

access to data and information of their own territories.

1.1.3 A brief history of mapping Africa

During the late 1800s and early 1900s, atlas production in Africa boomed. Much of the mapping that took place at this time was motivated by colonial powers. Maps displayed the extent of colonial territorial control, and resource availability in the colony (Adeniyi, 1985). By 1949, 43 per cent of Africa had been mapped in this way. Between the late 1940s and early 1950s, aerial photography was introduced which resulted in further extensive mapping (Adeniyi, 1985). Reflecting on this era, Shand and Silayo (1996) note that seventy percent of all single nation atlases in Africa were produced between the years of 1955-1975, with production reaching its peak in the 1960s. Adeniyi (1985) notes that production was, however, uneven and at independence many African countries did not even have a complete topographic or aerial photographic coverage of their territory.

Nigeria stands as a typical example of the experience of African countries. In Nigeria during the 1950s, the British colonial administration made an effort to compile an inventory of the country's resources and land potential, and attempted to use this information to solve planning problems. When the British left, there was a period of 10 years where limited data collection occurred (Chukwudebe and Duru, 1995). The Canadian government was instrumental in helping Nigeria obtain aerial survey equipment for the production of large scale maps in the 1970s, but many of the urban master plans were still produced by foreign consultants. Nigeria lacked the skilled manpower and cartographic facilities to lead its own mapping project. Chukwudebe and Duru (1985) note that the first attempt made at automated cartography for census data was carried out in 1972, just before the 1973 census. The maps resulting from the effort were used in land use planning, monitoring of urban spread, resource inventories, study of infrastructure and communications development, and in nature conservation. Although aided by foreigners, the benefits of modernising the mapping process has led the country to affirm that "whenever planning encounters the need for sizeable amounts of spatial data which change or fluctuate with time, the recourse to computer-assisted cartography becomes almost mandatory" (Chukwudebe and Duru, 1985:248).

Shand and Silayo (1996) suggest that investment in health care and education holds greater priority for most African countries than investment in national mapping projects. Increasingly however, a link is being made between the use of the computing environment and solving problems in the areas such as health and education. Although the desire to adopt information systems is now strong in many African countries, there are still considerable constraints which have to be overcome to ensure successful utilization of the technology. These constraints lie not only in the lack of money to buy the necessary equipment, but in "unreliable power supplies, unsuitable operating environments, and by inadequate maintenance agreements for computing equipment that has been imported or donated as part of foreign aid programmes." (Shand and Silayo, 1996:13).

Despite the presence of one or more of these constraints within their borders, several African countries have actively adopted more modern methods of mapping. Automated cartography seems to have laid a natural path for those wishing to produce a volume of digital maps relating to their country. Geographic Information Systems has taken this further, allowing the production of an interactive series of maps and related data collated in the form of a digital or electronic atlas. Several African countries have now gone from having barely enough updated paper maps describing their territories, to having their countries described in a digital national atlas. Such countries include **Kenya** [*Population Atlas of Kenya* (Fox, 1995)], **South Africa** [*Environmental Potential Atlases* (Van Viegen et al., 1998)], **Tanzania** [*Digital National Atlas of Tanzania* (Shand, 1996)], and **Swaziland** [*Tourism Potential Atlas of Swaziland* (Van Riet, 1998)].

1.1.4 Digital atlases

Digital maps and atlases are not intended to replace their printed paper counterparts but are intended to provide a new dimension to atlas information with increased flexibility and information storage capacities. Keller (1995) describes the national atlas of Sweden which provides its users with information in both digital and conventional formats. If interested by images in the paper atlas, the user is directed to the diskette version of the atlas which holds a lot more information. The Spanish national atlas maps the landscape in its natural state and then again displaying it with its environmental problems whilst the French national atlas aims at depicting phenomena such as the distribution of crime, AIDS and unemployment

(Keller,1995). This type of information is "a far cry from the visiting card concept national atlases once had, but it is with atlases like these that society's problems can indeed be tackled" (Keller,1995:19). It has been suggested by Taylor (1991) that just as maps were the tools of navigation and exploration, so they are now instruments of interactive computer navigation.

Digital atlases may be classified according to their analytical capabilities, ranging from "view only" at one end of the scale to those with considerable interactive abilities at the other. It is predicted that in the future "Instead of turning pages in a book of maps...the atlas user will manipulate maps on a microprocessor and interact with displays before her" (Monmonier,1985:137). The digital atlas has a number of characteristics not experienced in the conventional paper atlas. In **Table 1.1** below, characteristics of the traditional paper atlas are listed against those of the digital atlas.

Table 1.1: Characteristics of conventional and digital atlases

Characteristics of a conventional atlas	Characteristics of a digital atlas
1. Often seen as a series of small scale maps bound in a book	1. "Digital book of geographic maps of the world, comprising both graphics and descriptive information" (Department of Environmental Affairs and Tourism,1994:4-1)
2. Map order requires careful thought	2. Map order is not a concern - images can be linked in multiple directions
3. Page size limits the number of images that can be included	3. Stores large amounts of both graphic and attribute data which can be manipulated and analysed. Limitation is memory size of the computer
4. Maps are static - the user has no control over map parameters or display	4. The user has control over the map parameters displayed e.g. map content, legends etc.

5. Paper maps are often outdated and not easily updated	5. Quick, efficient production and easily updated
Characteristics of a conventional atlas	Characteristics of a digital atlas
6. Considered to be aesthetically pleasing	6. Inferior draughtsmanship quality in comparison to hand drawn maps
7. Presentation as a book in paper format can be unwieldy to use and store due to size	7. Presentation on diskette is compact
8. Analysis is limited. Patterns can be identified depending on the presentation of the maps. The nature of analysis is not determined by the user	8. Graphic and attribute data can be manipulated and analysed
9. Complete coverage for developed countries. Outdated or incomplete coverage for many developing countries	9. Patchy data coverage due to lack of digital data

Sources: Coppock and Rhind (1991); Department of Environmental Affairs and Tourism (1994); Keates (1989); Perkins (1995); Raveneau, et.al. (1991); Rystedt (1995); Shand and Silayo (1996); Taylor (1991).

1.2 Context of the Research

Very few atlases have been published in Africa during the 1990s. What is clear however, is that "in the near future many countries may be faced with the dilemma of whether to go digital or remain with existing analogue methods" (Shand and Silayo, 1996:13). Presently, Swaziland is still pursuing conventional methods of atlas production. The first schools' atlas of Swaziland was published in 1970 by Williams Collins of Johannesburg and was revised twice. The second edition was published in 1974, revised in 1974, 1976 and 1977. The third edition came out in 1978, with revisions in 1982, 1983, 1984, and 1985. It was reprinted in 1986. A.S. Goudie and David Price Williams produced a general atlas of Swaziland in 1983 which was printed in the country under The National Trust Commission. Macmillans

published an atlas for Swaziland in 1991, and reprinted it in 1997. They will be re-printing the atlas in 1999 (Briar,1997:pers.comm.).

Since July 1998, Swaziland has actively pursued an extensive automated mapping project headed by the Surveyor General's office. At the end of 1997, the government paid for a GIS consulting firm in Pretoria, South Africa, to carry out a tourism potential analysis of Swaziland. The result of this work was presented as the *Tourism Potential Atlas of Swaziland* (Van Riet,1998). Taking this interest in the automated environment to its natural conclusion, Swaziland could well join Kenya, Tanzania and South Africa in the development of a digital national atlas. Such an atlas could serve as the basis for a national database which could be used to answer future queries similar to the Swaziland government's tourism potential request.

It is easy to become over confident with the potential successes that technology put to practice, can hold. It is essential that one keeps in mind the existence of the potential constraints that exist in Africa. This thesis sets out to produce a digital population and environment Atlas of Swaziland. The production and utility of digital atlases in Africa will be appraised using the experience of the production process in this and other African digital atlases. A thorough investigation into issues surrounding the use of technology in Africa will be made and the real potential of such digital products, established.

1.3 The Study Area

The Kingdom of Swaziland lies to the north east of South Africa. The country has a total land area of approximately 17 500 square kilometers. Swaziland is landlocked, sharing international borders with South Africa for 430 kilometers to the north, south and west and with Mozambique for 105 kilometers to the east (see **Figure 1.1**). By July 1998, Swaziland was estimated to have a population of 912 876 people (Mamba,1998:pers.comm.). The *Population-Environment Atlas of Swaziland* covers the entire country.

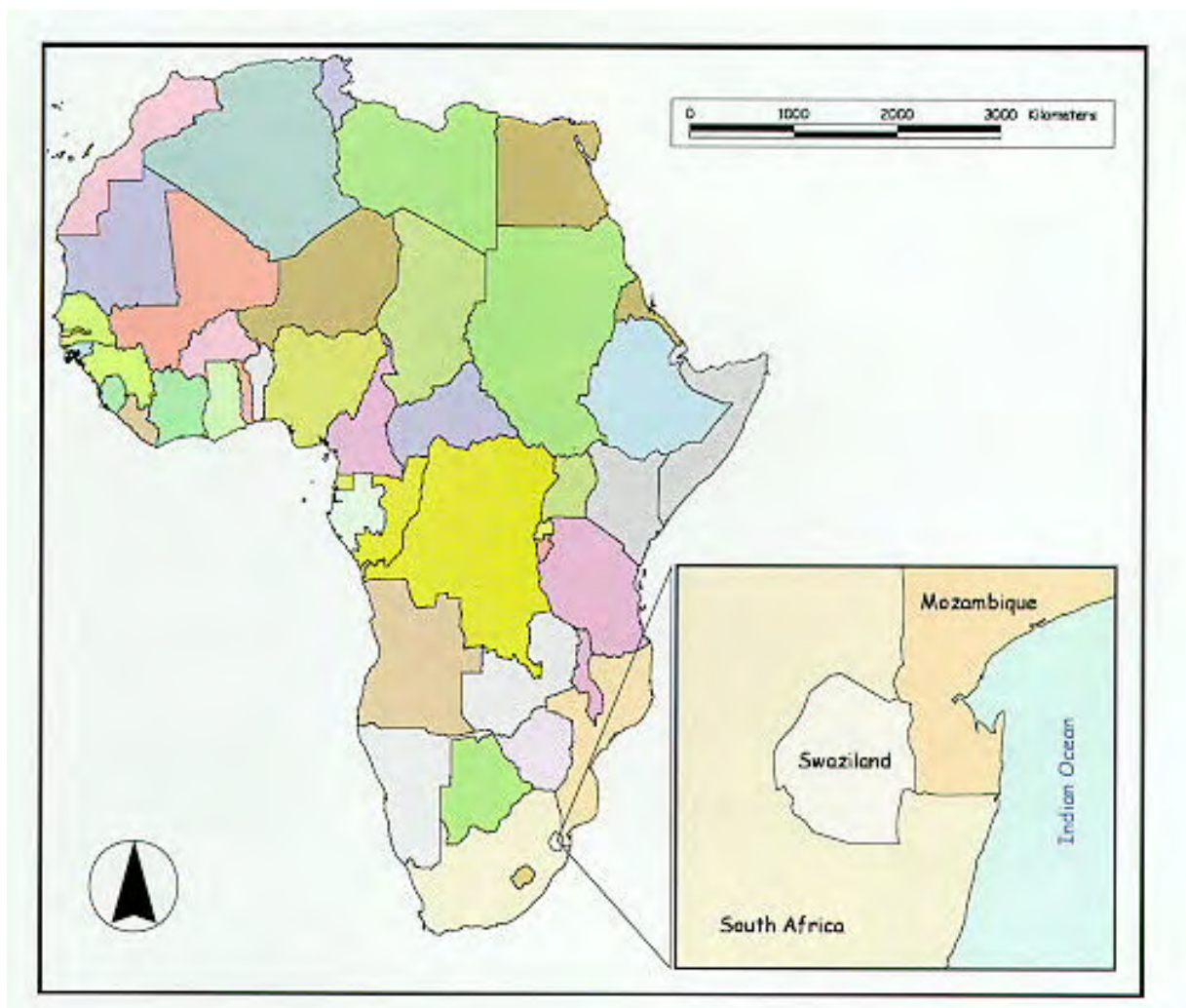


Figure 1.1: Study Area - The Kingdom of Swaziland [Source: SCT (Corbett,et.al.1997)]

1.3.1 Putting the Study Area in context; digital mapping activity in Swaziland

i) Cadastral database project - The Department of Natural Resources and Energy in the Ministry of Works has developed a cadastral database for the entire country (Johnson,1998;pers comm.). The project was initiated by the United Kingdoms' Department for International Development (DFID) and was intended as a management tool for storage and retrieval of cadastral files that would otherwise be stored in a filing cabinet. The database holds all information recorded in the manual files, including data such as plots which are legally eligible for subdivision and those which are not. The product is PC (Personal Computer) based and was produced using UNIGIS software. It provides information on the cadastral boundaries to an accuracy within centimetres.

The project leader noted that the system used is now a little outdated and compatibility with more up to date packages such as ARC/INFO could be a problem (Johnson,1998;pers.comm.). The department would like to bring the database in line with more common formats like AutoCAD.

The departmental policy is that they are purely data providers; no analysis is carried out as yet. The database is available for sale as a whole or in parts and thus far, the users have included ESCOM (Electricity Supply Commission of South Africa) who purchased the entire package, GIS Business Solutions in Johannesburg, South Africa who bought the rural areas information and the Mbabane City Council and the Water Services Corporation of Swaziland who bought the Mbabane regional data.

ii) Digital mapping project - A digital mapping project aiming for coverage of the entire country began in the Surveyor General's Office in July 1998. The project is being carried out in conjunction with the Ordnance Survey Team of the United Kingdom. A team of consultants from the UK visited the country in July to review the progress of DFID funded projects and to help get the project started (Ministry of Public Service,1998). The project is being headed by Mr Sydney Simelane and a team of trained local manpower.

The project has begun with the digitizing of eight main urban areas in the country; Piggs Peak, Mbabane, Nhlangano, Lavumisa, Manzini, Matsapa, Siteki and Hlatikulu (Simelane, 1998:pers.comm). Detailed data is being captured for each of these urban areas, from a series of 1:2500 aerial photographs on three photogrammetry stations. All topographic data as well as walls, hedges, buildings, electricity and telephone lines are included. This level of detail will only exist for the urban areas in the near future. To cover the rest of the country, 1:10 000 maps will be used as base maps from which data will be digitized manually. The photogrammetry stations used in data capture belonged to the department before the project began and whereas before they were linked to drawing tables, they are now each linked to a computer donated by the DFID for the project. Pre-existing data belonging to the department which had been captured when the photogrammetry stations were linked to drawing tables is being digitized manually with updates being included.

The aerial photography was contracted out to the Aircraft Operating Company in Johannesburg. The Manzini - Matsapa corridor was due to be photographed within the first weeks of August 1998. Mbabane and Piggs Peak will be photographed in 1999, as the photographs the department have need updating.

All of the computers in the department are linked by an internal network so that any updating or editing of the maps is accessible on all of the machines (Simelane, 1998:pers.comm.). In the editing room, digitized features are assigned codes which can be referred to in the accompanying feature code directory. For example, the feature labelled FC26 represents a wall, and the feature labelled FC207 represents a Donga Top. A brief definition of each term is given in the code directory to avoid any confusion to the user. The South African developed uSMART version 6, (which appears to be a drawing package) is being used for editing. As the package has been developed in the southern hemisphere, it was noted that simple features such as understanding the South African LO coordinates system make the package extremely user friendly (Simelane, 1998:pers.comm). As the project is in its infancy, trial maps are being printed on a Hewlett Packard Inkjet plotter and in July 1998 the operators were just beginning to experiment with the introduction of colour.

By the 31st December 1998, the department hoped to have digital maps for sale, available in four formats; i) hard copy, ii) DXF, iii) MicroStation and iv) AutoCAD. Although the department has been given a head start, the project is costly and Mr Simelane noted that his department was hoping that by September 1998 the Japanese government would be helping with funding for the project so that the completed 'National Topographic Database' may be realised (Simelane,1998:pers.comm.).

Inexperienced in the handling of digital data, the department currently has a list of suggestions for legal conditions which could be attached to the data. Meetings still needed to be held to establish the legal documentation. The department has had requests in the past for street guides, to include in tourist publications, and have had to say yes as there are no formal policies regarding the use of the information. It was noted by Mr. Simelane that in future, access to the data will probably be more restricted than it is now.

Due to the fact that other departments are slow to computerise, links between the various departments are weak and as a result the potential uses of shared data go unrealised. Although the Surveyor General's Office has had nothing to do with the Census Department in the past the two are now tentatively linked through a rural electrification project that is being investigated by the Census department. The project is looking to provide electricity to schools that do not have it and the Surveyor General's Office has been requested to use its skills from the mapping project to map the needy areas. Although the department wants to be seen as data providers for the present, it would appear that projects such as the rural electrification programme may require some analysis.

iii) GIS in Swaziland - Mr Erik Van Waveren, a soil and water conservation specialist (Netherlands Engineering Consultants) working for the department of Land Use and Planning in the Ministry of Agriculture indicated that their department made use of GIS in the form of ArcView and IDRISI. They have captured several covers for the country which have been overlaid to produce their own land use potential maps. Whilst the department was using the GIS systems for their visualization capabilities, they were not using them to their full analytical potential. Analysis has not been possible up to now due to a lack of skilled personnel (Van Waveren,1998:pers.comm.).

Any requests for access to the data have to be addressed to the senior land planning officer. The outcome of these requests is never certain. There are no guidelines for digital data use within or between departments and as a result of this, the Department of Land Use and Planning understandably tends to be very careful about to whom they grant access (Van Waveren,1998;pers.comm.).

1.4 Aim

To create a digital atlas of Swaziland's environmental and population information so as to facilitate an appraisal of the production and utility of digital atlases in Africa.

1.5 Objectives

1. Collect numerical and spatial data for Swaziland.
2. Establish the extent and type of mapping activity in the Kingdom and other African countries.
3. Produce a population and environment atlas of Swaziland.
4. Critically assess the process and methods used.
5. Produce an open-ended questionnaire for the producers of the *Population Atlas of Kenya* (Fox,1995), *ENPAT* (Van Viegen et.al.,1998), the *Digital National Atlas of Tanzania* (Shand,1996), *Spatial Characterization Tool* (Corbett et.al.,1997), and *Tourism Potential Atlas of Swaziland* (Van Riet,1998) to ascertain production problems and actual utility of the product.
6. Develop appropriate guidelines for atlas production.

1.6 Methods

The methods are introduced below in relation to each objective.

1. Collect numerical and spatial data for Swaziland.

Initial contact was made with the census commissioner of Swaziland (Mr D.M. Lukhele), before the project started. A general outline of what was thought to be needed for the project was given to him and he supplied the numerical and spatial data available to him.

The 1:50 000 scale maps of Swaziland were needed for the capture of schools, hospitals etc. The collection held by the Geography Department at Rhodes University was incomplete for the country and

the production dates of the available maps varied considerably. It was necessary to order the most recent series from Map Office in Johannesburg. The Department of Land Use and Planning in the Ministry of Agriculture were contacted for their environmental data, and a Digital Elevation Model was ordered from ComputaMaps in Cape Town.

The following **numerical data** was collected:

- a) Statistical volumes for the 1986 Census were obtained from the Census Department in Mbabane, Swaziland. Statistical data for the 1997 census, was to be obtained in July 1998; it will only be available in January 1999 and will therefore not be included in the atlas.
- b) The Bird Atlas of Swaziland (Parker, 1994) was obtained to be used as an example of the type of data that could be included in a national atlas.

The following **spatial data** was collected :

- a) 1:250 000 topographic map of Swaziland (1989) (from the Census Department in Swaziland)
- b) Thirty two 1:50 000 map series covering Swaziland (1991) (from Map Office in Johannesburg)
- c) 1:250 000 sepia transparency of the 1986 enumeration areas (from the Census Department, in Swaziland)
- d) 1:250 000 sepia transparency of population distribution in Swaziland (1986) (from the Census Department in Swaziland)
- e) 1:250 000 sepia transparency of population density in Swaziland (1986) (from the Census Department in Swaziland)
- f) 1:75 000 dialine copy of the provisional 1997 enumeration areas (from the Census Department, in Swaziland)
- g) IDRISI images for present land use, land tenure, moisture zones, thermal zones, agroecological zones and vegetation cover (from the Department of Land Use and Planning in the Ministry of Agriculture in Swaziland).
- f) A 30 arcsecond (nominal 1 kilometre grid resolution) Digital Elevation Model (DEM) for Swaziland (from ComputaMaps in Cape Town).

2. Establish the extent of digital mapping activity in the Kingdom and other African countries.

Through informal interviews with Mr D.M. Lukhele (Census Commissioner of Swaziland), Ms. Petrunella Mamba (Statistics Department), Mr. Sean Johnson (Surveyor General's Office) and Mr. Sydney Simelane (Surveyor General's Office), mapping activity in the Kingdom will be examined and documented. Through a review of literature, examples of mapping activity in other African countries will be established.

3. Atlas production

Data for the atlas was captured on a PC with a 486 processor using PC ARC/INFO. Subsequent work was carried out on a 486 and a Pentium using ArcView 3.0 and IDRISI for Windows. More detail will be given in Chapter 3 with regards to the methods of production as they will be examined in conjunction with the problems experienced.

The following **population covers** were captured:

- 1) enumeration areas - polygon topology from 1986 census enumeration map (1:250 000 dialine copy)
- 2) international boundary - line topology from 1:50 000 maps
- 3) regional boundaries - polygon topology from 1:50 000 maps
- 4) towns - point topology from 1:250 000 topographic map
- 5) roads and railway - line and polygon topology from 1:50 000 maps
- 6) schools (training colleges and the University) - point topology from 1:50 000 maps
- 7) electricity transmission lines - line topology from 1:50 000 maps
- 8) tourist information covers:
 - a) border posts, hotels, motels and lodges - point topology
 - b) golf courses, airstrips, airports, hot springs, the main water sports dam, waterfalls renowned for their natural beauty, Sebebe Rock, horse riding stables, the main royal residence, parliament and the national museum - point topology from 1:50 000 maps
- 9) hospitals, clinics and health centres - point topology from 1:50 000 maps
- 10) mines (used and disused) - point topology from 1:50 000 maps
- 11) police stations - point topology from 1:50 000 maps

12) post offices - point topology from 1:50 000 maps

The following **environmental covers** were captured (the source maps are indicated in brackets):

- 1) bird species distribution - grid generated in PC ARC/INFO with relevant information, as a sample
- 2) forested areas - polygon topology from 1 :50 000 maps
- 3) nature and game reserves - polygon topology from 1:50 000 maps

Covers included in the environmental section of the atlas, but not created by myself:

- 4) land use (1994 data - from the Ministry of Agriculture, Swaziland)
- 5) land tenure (1994 data - from the Ministry of Agriculture, Swaziland)
- 6) moisture zones (based on rainfall amount, distribution, length of growing period (from the Ministry of Agriculture, Swaziland).
- 7) thermal zones - based on mean annual temperature (from the Ministry of Agriculture, Swaziland)
- 8) agroecological zones - combination of physiography, moisture zones and thermal zones (from the Ministry of Agriculture, Swaziland).
- 9) vegetation types (from the Ministry of Agriculture, Swaziland)
- 10) Digital Elevation Model for Swaziland (from ComputaMaps, Cape Town)

4. Critically assess the process and methods used.

The technical problems encountered during the production of the proposed *Population-Environment Atlas of Swaziland* were noted in a journal and will be used to assess the process.

5. Produce an open ended questionnaire for the authors of the *Population Atlas of Kenya* (Fox,1995), *ENPAT* (Van Viegen et.al.,1998), the *Digital National Atlas of Tanzania* (Shand,1996), *Spatial Characterization Tool* (Corbett et.al.,1997), and *Tourism Potential Atlas of Swaziland* (Van Riet,1998) to ascertain production problems and actual utility of the product.

A questionnaire was sent to the producers of the *Digital National Atlas of Tanzania* (Shand,1997), *Spatial Characterization Tool* (Corbett et.al.,1997), *ENPAT* (Van Viegen et.al.,1998) and the *Population Atlas of Kenya* (Fox,1995) (see Appendix B). The questionnaire was conducted over the

telephone for the producer of the *Tourism Potential Atlas of Swaziland* (Van Riet,1998).

6. Develop appropriate guidelines for atlas production in Africa

Using the problems experienced during the production of the population environment Atlas of Swaziland, input from atlas producers and insight gleaned from relevant literature, guidelines for the creation of digital atlases in Africa will be suggested.

Thesis Outline

This thesis is divided into six chapters and is submitted with a compact disk (CD-ROM) holding the population and environmental atlas of Swaziland. **Chapter Two** provides a review of literature relating to issues surrounding the research. Technology utilization and development in Africa are examined and Geographic Information Systems (GIS) questioned as appropriate technology for use in Africa. Examples of international and African digital atlases are considered, supported by an overview of digital mapping projects in Africa. A descriptive account of the production process and problems encountered with the creation of the digital population and environmental atlas of Swaziland constitutes the bulk of **Chapter Three**. This chapter is essentially a record of the results of the research. **Chapter Four** appraises the production of digital atlases in an African context. To achieve this, an analysis of the problems experienced in the production of the atlas of Swaziland and three other African atlases, is made. The utility of digital atlases in an African context is appraised using the atlas of Swaziland as a case study. The capabilities cited as examples in this chapter can be viewed by opening the atlas from the attached CD-ROM and following the steps outlined. **Chapter Five** suggests guidelines for production in an African context followed by potential utilisation of digital atlases in the future. Conclusions have been drawn in **Chapter Six**.

Chapter Two: Literature Review

"Cultural dependency means people in our country have to brush their teeth three times a day, even if they don't have anything to eat" (Cardova,1984:31)

2.1 Introduction

This chapter attempts to set the stage for an appraisal of digital atlas production and utility in Africa, through a presentation of related topics from a variety of authors. Topics discussed include an examination into the perceived role of information technology (IT) in development in Africa since the early 1980s. Factors affecting the successful utilization of IT in Africa are outlined, leading to the question of whether or not GIS is appropriate technology for the continent. To answer this question, current GIS activity in the form of digital mapping projects and digital atlases in African countries are examined.

2.2 Perceptions of the role of information technology in the developing world

In the 1950s and 1960s, access to information began to be recognised by researchers and decision makers as a powerful contributor to national development. Reflecting on this time period, Stover (1984) states that a country or area without access to some sort of mass communication in the form of newspapers or television was seen as lacking the "capacity to develop community projects and deal with community needs" (Stover,1984:7). Countries with poor communication networks do rely in part, on word of mouth for their information dissemination. Whilst it may take longer, one could argue that the lack of mass communication facilities in a country does not make the identification of community needs and the development of community projects an impossible task. In the remote areas of Africa, rural communities seem to be able to organise their lives fairly well without the presence of electronic communication links. One does have to accept of course, that to guarantee efficient organization of daily life as communities grow in size, the need for faster methods of information dissemination does arise.

In the developed world by the mid 1980s, "reliance on technology to perform a wide range of functions [had] come to affect virtually every sphere of human activity" (Rush,1984:35) with much research being

carried out on the role of technology in the identification and resolution of environmental degradation, unemployment, crime, resource utilization and service provision distribution. The links between technology and the achievement of development goals was suggested by Rush (1984) to have encouraged governments of the developing world to adopt some form of information technology. According to Stover (1984), the use of computers for teaching became increasingly important in developing countries from the mid 1980s, holding the possibility of relieving teacher shortages. The most important tool a computer could provide developing countries with at this time, has been identified by Stover (1984), as being the management of information in both social and commercial situations.

Stover (1984) highlights some of the main view points of the mid 1980s relating to the role of information technology. IT used as a means of communication, was seen as having the ability to contribute to **social development**. For example, active involvement in the creation of a locally relevant data set for use in establishing local goals and aspirations could be a powerful tool in uniting people in a community. Information collected, stored, processed and disseminated provides the opportunity for the discussion and exchange of ideas and culture thereby contributing significantly to education, organisation of development projects and problem solving (Stover,1984). There is little doubt that this idea is relevant to African countries in the 1990s. IT was also seen as having a role to play in the **economic development** of a country. Used to develop and maintain a resource database for a country, IT still holds the potential to contribute to the creation of national guidelines for resource utilisation and the outline of national priorities which have a direct effect on the economy. Stover (1984) notes that the rural poor are often omitted when it comes to outlining national goals. One might feel that in many areas of Africa, this is still very much the case. The contribution of indigenous knowledge, perspective and experience which could be drawn from local people has the potential to be of great value as suggestions towards national development guidelines and objectives. **Political development** was seen as being another area which could benefit from IT, through record keeping, evaluation of public opinion, tax collection and budgeting. This view has changed little in the 1990s with the ever increasing number of governmental departments in Africa relying on IT.

Despite the best of intentions, many African countries in the mid 80s did not succeed "in mobilizing...full

scientific and technological potential for constructive economic development" (Savane, 1984:372). Several authors have suggested reasons for this. Lyon (1988) notes that there were certain cases in which the application of more technology, was entirely inappropriate. Ghosh (1984) criticises the type of research carried out in the developing world at this time as setting "forth solutions to problems for which there are no users" (Ghosh, 1984:45). Savane (1984) presents three distinguishing features of technological research evident in Africa in the eighties. The first point states that much of the research carried out was still being headed by foreign workers and institutions, presenting the possibility of development objectives conflicting with those of the receiving country. The second point suggests that the scope of much of the research carried out at University level, was exceedingly narrow and had little to do with the daily lives of the general population in African countries. According to Savane (1984) the reason why students often embarked "on research projects devoid of any practical significance for their country [was] that many of the university teaching staff [were] still foreigners" (Savane, 1984). The final observation suggests that in the rare cases where research did have a practical use "the State may decide to oppose, or at any rate minimize, the scope of discoveries which if publicized might conflict with the interests of highly influential business circles" (Savane, 1984:373). All of these observations should be considered valuable to African countries today as they can be used as an example of what to avoid. Bringing these observations into the 1990s, Goodchild (1992) notes in reference to the developed world, that whilst research carried out in academic institutions is generally useful, it "is generally poor at providing the means of implementation" (Goodchild, 1992:42). This could very well be the case in African countries as well. Bearing in mind that having foreign members of staff lecturing in Universities is not necessarily a bad thing, the type of research carried out and its implementation could be investigated a little more thoroughly if African governments are concerned.

Lyon (1988:18) suggests that "information [was] not steadily diffused in a general way through all social echelons" during the 1980s. Despite the fact that IT was and still is considered to provide "access to new areas of knowledge which [people could] use to better their welfare" (Savane, 1984:372), information in Africa in the 1990s is still restricted to those who can afford the hardware and software required and to those who have the skills needed to understand the information. The Internet has brought a number of Africans in touch with ideas and cultures from the other side of the world, but a large majority remain

without the equipment or money to gain access. According to Woods (1993), much technological development in Africa in the early 1990s has been focussed on market related applications such as financial services, public sector management and the military. Social applications such as the diagnosis of plant, animal or human disease, land use planning and management of resources have not received nearly the same amount of attention. Woods (1993) accepts however that it is only recently that computer hardware and software has become affordable enough for widespread use in the social sector and provides a wealth of examples of computer technology put to use to foster social development initiatives in developing countries. In Bali, monks have been using computers to aid the expansion of an old irrigation programme. In Costa Rica, it is estimated that half the children of school going age have the choice of a computer based education, greatly improving access to information for both students and their parents, who also make use of the IBM programme. An example of the use of computers used to store demographic data and the occurrence of disease in remote villages in Peru, is given. These computers are powered by solar panels. Provided with initial instruction, the villagers have been able to make continued use of the technology by identifying and monitoring seven common diseases amongst their people. In the United States, interactive technology has been used to teach US military GIs with limited education, how to look after and operate sophisticated weaponry. The same type of technology has apparently also been used on migrants; to teach the nomads of the Sahara, paddy field workers in Bangladesh and people living in the hills of Nepal to operate equipment for oil drilling in the Gulf. If computer technology has been successful in these countries, perhaps a closer look at the case studies should be carried out to see if there are any lessons that could be learnt for Africa.

Some of the patterns which have emerged amongst the users of interactive technology have been observed. According to Woods (1993), in general people are no longer net receivers of information, but have become processors of information. Interactive environments provide benefits of not only allowing for learning-by-doing involvement, but can also provide the most updated information to the user. The driving force behind learning in an interactive environment no longer derives from a basic need, but through curiosity instead. There is little stronger motivation to be had than that which comes from a person wanting to carry out a task rather than being told to do so. Woods (1993) advocates the improvement of existing community information centres to incorporate interactive technology. Whilst these

centres provide reading material to people, access is limited to those who can or want to read. Interactive technology holds the potential to "make these centres far more comprehensive and useful" (Woods,1993:91). An example of agricultural recommendations being shown in pictorial form to rural farmers, is given.

The potential use of IT in developing countries is often just that; potential. In many areas of Africa, IT utilisation fails through excessive under-utilisation of computer systems which have been installed. For a variety of reasons which will be elaborated on below, Ojo (1993) notes that some plans are never actually operationalised, projects are often abandoned and inappropriate automation of certain functions is in some cases carried out. Inappropriate software for desired applications and research results not meeting practical expectations, all contribute to the failure of IT utilisation in Africa. The following section describes six additional factors limiting successful utilization in Africa.

2.3 Factors affecting successful technological utilization in Africa

Political instability plagues numerous African countries for a variety of reasons. This instability often holds negative implications for information technology development in the affected countries. Kasongo (1993) notes that where monetary and human resources could be used to foster IT, they are instead used to support military efforts to maintain political power. IT is labour saving; a feature which would not be seen favourably in areas of high unemployment. To maintain pre-independence promises of job creation, Kasongo (1993) suggests that some governments would undoubtedly resist investing in such technology for fear of losing popularity with the masses.

Political turmoil disrupts many development projects, creating an unfavourable climate for progress. In the instance that a new government takes over, any development plans made under the previous rulers are likely, according to Kasongo (1993) to be ignored. Thinking of the civil war in Angola today (1998) where people are fleeing from the rural areas to avoid the fighting, and life in the cities is not much better, the progress of development projects simply cannot be certain.

In the 1980s, Rush (1984) notes that choosing the type of technology for a country, was highly

dependent on a number of decision makers. These decision makers often approached their choice from entirely different angles, having very different objectives in mind. The transnational enterprises for example were more likely to choose technology which helped them achieve their aims of maximising global profits, whilst national firms were more likely to want technology which allowed for maximum profits at a local level. Redistribution of wealth, modernization, increasing employment as well as the preservation of power, may be the aims of a national government and their adoption of technology will be affected accordingly. Other decision makers include small firms, local communities, and military forces. The "distribution of influence which each of these actors has over the available resources, and the coalitions which form between different actors, will be a significant factor in the innovation and diffusion of techniques and the direction in which development takes place" (Rush, 1984:36). There is little doubt that this is relevant in African countries today.

Often when provided with the means to communicate, the government in power is tempted to control information dissemination for their own means. If political intentions remain loyal to what is best for the people as opposed to the party, IT could augment social awareness, result in mass mobilization and increase the ability to meet basic needs by the government. In such a situation, governments would not need to sabotage the technology as "greater public support for the institutions of the state and the increased cohesion of the nation" (Stover, 1984:145) would follow. In countries where governments are used to controlling every sphere of life, the idea of the free flow of information can be abhorrent. Information with restricted access is of little use to anyone.

Socio-economic concerns have the ability to undermine successful utilisation of IT in Africa. Involving the training of a small percentage of people at high cost, IT is blamed for widening the gap between rich and poor. Kasongo (1993) notes that a reliance on the developed world for advice, has resulted in a growing criticism that dependence on the developed world is being strengthened. Ojo (1993) suggests that dependence on the developing world needs to be eased off, with the fostering of an indigenous IT capacity. A common socio-economic problem affecting African countries today, is the loss of the few people who have become skilled in IT, to the developed world. This 'brain drain', is described as a "cruel transfer of skilled labour" (Kasongo, 1993:5).

A third major factor, is the lack of skilled **manpower**. In GIS the requirements are spatial knowledge for problem solving and skills in using computers. Expertise in terms of problem solving ability, decision making experience and computer tool understanding are of utmost importance according to Nyerges (1993). The adoption of advanced technology often "requires the adoption of methods of management and organisation employed in the so-called 'advanced' countries" (Rush,1984:37) and this requires specific training. The cost of training people is often too expensive, but "even the best technical system cannot execute better than its operators are able to achieve" (Kasongo,1993:6). A government has to weigh the costs and the benefits of running imported equipment and using imported personnel if neither are available locally.

Degree courses in computer science and information systems need to be intensified in many African countries, possibly training people more in their local language to ensure a complete understanding of the work. Odedra (1992) comments on the courses which are available in countries such as Ghana, Malawi, Nigeria, Tanzania and Zimbabwe noting that they are often criticized for their lack of practical training. Limited facilities make teaching computer courses all the more difficult. Closer attention paid to the curriculum may ensure a better trained and educated student, ready to fill the gap in the manpower resource base.

In an information society, the importance of a reliable **infrastructure** is paramount. In African countries telephone systems exist, but in many cases they are unreliable with "the entire telephone system crippled after a rainfall" (Kasongo,1993:6). Gardner (1993) suggests that use of the latest telecommunications technology in the form of cellular communications, could be investigated. Power cuts are often experienced in Africa, which interrupt work on computers which do not have their own battery packs. On Christmas Day 1998 in Swaziland there were three power cuts during the course of the day without thunderstorms being present. Uninterrupted Power Supply (UPS) systems have helped in this regard, but they also increase the overall cost of equipment. Woods (1993) notes that local options such as the use of solar or wind power could be considered as possible power supplies. Gardner (1993) notes that the power surges can ruin IT equipment which is why many private houses in Swaziland and possibly elsewhere in Africa, are fitted with voltage regulators which cut the power every time a surge is detected.

Poorly maintained roads in many African countries hinder the transportation of fragile computer equipment and in some cases result in the damage of expensive equipment.

Due to a reliance on international expertise, many African governments do not have their own **national policy guidelines** pertaining to decisions on the importation of computer products. Policy guidelines are especially important to ensure that limited IT knowledge is not used to the detriment of the receiving country.

Although writing in the mid eighties, lessons can be learned from the observations which Rush (1984) has made with regards to the three forms of control inherent in technology transactions. Falling prey to any one of these three, could have detrimental effects on successful technology utilisation in the developing world. The first is referred to as a *direct sale* where technology is purchased from capital-goods producers. "Firms in developing countries buy in this form, either because it will give them a competitive advantage in their product markets...or in order to survive against competitors" (Rush,1984:38). Being pressured into making a choice, mistakes can be made possibly resulting in the purchase of inappropriate technology. The second form of sale is a *process packaged* sale which has an additional feature attached to it to attract the buyer. It is often an "innovated component for which the seller has monopoly control" (Rush,1984:38). The buyer in this case is to a certain extent, at the mercy of the producer for continued user support. Trying to ensure user support from overseas companies if not available locally, has the potential to be problematic. This is why national guidelines are so important. The third form discussed, is the *project packaging* sale. The developer of this technology is often also a producer of the goods and the "seller, therefore, has a greater interest in the way this technology will be employed and will attempt direct control of its uses" (Rush,1984:39). In this case, dependence on the producer is never broken, bringing into question whether or not the technology really is appropriate.

Local investors often feel safer investing in transnational corporations than in local concerns, "whether or not the technology is locally appropriate" (Lyon,1988:112). Locally developed technology is often seen as inferior to that purchased from the first world. If "Third World countries are to compete in the world

market" (Lyon,1988:112), the purchase of modern technology appears to be the means by which to do so. As a result of this, transnational corporations are some of the most significant decision makers in the choice of technology in African countries.

It is suggested by Savane (1984) that "national resources can be developed far more easily where technologies that respond to genuine needs have been developed as a result of a proper research policy" (Savane, 1984:372). National policy guidelines could be used to ensure that governmental and non-governmental organisations are forced to carry out proper research into technology choice and use. They could also be used to make sure that payment for equipment which is ill suited to a country's IT needs or is obsolete, is avoided. Used as a checklist, policy guidelines could monitor the degree of control held by a foreign body which may be purchased along with the technology. Bassole (1998) notes that governments need to come up with a national policy on IT utilization to make objectives and priorities clearer. Although policies on the adoption of hardware and software are important, a policy on data management will be one of the most important issues for African governments to address. The development of national guidelines still may require advice from other countries; developed and developing. India could well provide valuable input given their experience in the field.

There are **socio-cultural** concerns which might hinder successful utilisation of IT. Many systems are seen as "the product of a rationalist Western culture with a mechanistic world view based on things rather than humans - a culture quite far removed from a traditional African culture" (Ojo,1993:36). If this observation is true, many software packages and programs may not be as successful in their use as expected. Software is unlikely to be written in the mother tongue of the user, and this could well affect understanding and appropriate use. Culturally, "for any technology transfer to be successful, the local ways of thinking and behaving must be taken into account" (Gardner,1993:15).

Misunderstanding the nature of the culture within which a system is adopted, can hinder the success of its use. Kasongo (1993) mentions the fact that in African culture, the extended family plays a significant role in society. A lot of pressure is placed on the individual, to supplement his income to support this family. Inefficiency, low productivity and impaired concentration on the job at hand could be related to

this cultural pressure. It may be an environment which is not conducive to the way in which IT operates in the developed world. People are understandably reluctant to entertain alternative ideas on how to run IT systems profitably. If success is achieved in the developed world by following certain guidelines, it would take a large amount of self confidence to suggest alternative methods.

Rush (1984) considers the adoption of technology from the developed world to have had a disruptive effect on the fostering of an indigenous scientific capability. The suggestion is a valid one. If one has access to a product, why would anyone attempt to re-invent it. There is no need to re-invent software and hardware perhaps, but African countries could look at adapting what is available to suit their needs a little better.

Nyerges (1993) calls for an increased understanding of **human-computer interaction**. Geographic Information Systems (GIS) for example are being used each day by a wider range of people from varying situations. The success of GIS tasks is often affected by the working environment the operator is expected to function within. Environmental factors such as noise, temperature and lighting have all had a proven effect on the productivity of operators (Nyerges,1993). Unfortunately many operating environments are considered to be unsatisfactory in the African context (Shand and Silayo,1996).

Despite the adverse conditions which some African countries face, they are maintaining their path towards technological development and are depending on information systems to help them achieve their development objectives. "It may be argued that deficiencies in the use of IT are the least of the problems of a continent plagued by a history of exploitation, post colonial political difficulties, bloody civil conflicts, and extensive health, educational, demographic and economic problems..." (Gardner,1993:11). One has to keep in mind however, the possibility that some of these problems could be alleviated through the use of Information Technology.

2.4 Defining Geographic Information Systems (GIS)

According to Maguire (1991), Geographic Information Systems are a recent phenomenon, not more than 30 years old. The "recent origin and rapid rate of progress has not been conducive to the analysis and

definition of GIS" (Maguire,1991:9) and the fact that GIS is used by such a wide variety of people from different disciplines adds to the difficulty of its definition.

Geographic Information Systems have been born out of a variety of technologies and disciplines, namely Geography, Cartography, Remote Sensing, Photogrammetry, Surveying, Computer Science, and Statistics (Hobson,1993). The use of spatially referenced data has meant that Geography provides the framework for GIS. The value of manipulating data within a GIS would be limited without the ability to display results graphically. Cartography not only supplies source maps from which data can be captured, but has provided the basis of graphic display available within GIS (Hobson,1993).

In an attempt at defining GIS, Cowen (1988) outlines four standard approaches. The **process-orientated approach** focuses on the integration of spatial data into an information systems framework. The system is viewed in terms of processes of input, storage retrieval, analysis and ultimately, output of geographic information. Cowen (1988) argues that although this provides a good overview of what is inherent in a GIS, it is too broad. The author argues that the production of a digital atlas, which requires input, storage, retrieval, analysis and output of information could by the above definition, be seen as an operational GIS. A digital atlas is a product created within a GIS environment and is not necessarily a stand alone Geographic Information System. To arrive at a more refined explanation, the **application approach** attempts to define GIS in terms of the type of data that is used, namely "natural resource inventory systems, urban systems, planning and evaluation systems, management command and control systems and citizen specific systems" (Cowen,1988:53). This approach is praised for its display of the scope of GIS, but is criticised for the fact that it does not separate GIS from other data processing packages which use geographic information. The **toolbox approach** defines GIS in terms of the specific capabilities that should be found in the software, to carry out each of the features outlined in the process-orientated approach outlined above. Digitizing therefore could not be mistakenly defined as a GIS as it does not have the tools to analyse data. Finally, the **database approach** is outlined by Cowen (1988). This approach takes the toolbox approach one step further by emphasising not only the need for the existence of these tools, but the need for efficient interaction between the available tools.

Definitions of GIS differ from one person to the next. A surveyor, an engineer or a draughtsman would provide a different definition of GIS than a geographer or environmental scientist might. The reason for this is that the technology holds specific significance for each discipline. Whilst a geographer may be interested in the results of spatial analysis capabilities, the surveyor and draughtsman may focus more on the ability of a system to speed up drafting and design processes whilst maintaining precision and accuracy (Huxhold,1991:xiv).

Hobson (1993) outlines six specific categories of questions which can be answered using a GIS. These questions help define the technology. Using GIS, answers to locational queries can be obtained; the user is able to identify a specific area on the map and ask 'what is at?' the chosen location. Secondly, through querying the database, the user can ask where a specific feature is on the map. Thirdly, spatial trends over time can be identified. Fourthly, the user is able to identify the best, the shortest, the cheapest or the most effective routes on a map. The fifth category allows the user to question any spatial patterning which becomes apparent. Lastly, spatial modelling can be carried out where the user asks 'what happens if?' certain conditions change. According to Fincham and Piper (1991:7) it is the ability to pose and obtain answers to 'what if?' questions which "takes GIS beyond the simple mapping level to decision support status".

Three additional views namely, the map, spatial analysis and database views have been discussed by Maguire (1991) in an attempt at defining GIS. People who support the map view focus their attention on the cartographic capabilities of GIS; Tomlin (1990) is one advocate of this view. The GIS is seen as a map processing system where data sets are represented graphically in map form. These graphic representations are referred to as coverages, layers or themes (Maguire,1991). The answers to queries carried out are usually displayed in map form. Followers of the database view according to Maguire (1991) are more interested in the design and functioning of the database tool for complex queries of geographic data. The spatial analysis view concentrates on the ability to model spatial analysis and is suggested to be the most widely accepted view in the GIS community.

The best definitions may come from a description of what GIS is not. GIS is not a Computer Aided

Design (CAD) or Computer Cartography package, it is not a remote sensing system nor is it a database management system (DBMS). GIS has in fact been described by Maguire (1991) as a subset of each of these (Maguire,1991).

There is little doubt that the principles of 'Appropriate Technology' would be suited to the African situation. These technologies, as with intermediate technologies are expected to be "low in capital costs; they can be maintained without a high level of expertise; and they do not involve patents, expensive copyrights and royalties" (Yapa,1991:41). The question that needs to be asked, is whether or not the GIS technology defined above and digital mapping could fit within these principles or if African development initiatives are pinning their hopes on a dream. It has been argued that "Small planning offices in the rural areas of the Third World cannot afford the capital costs of PC ARC/INFO. It is not a technology that '...can be understood, controlled and maintained by villagers whenever possible, without a high level of Western-style education'. It is strictly copy protected; its use requires consultation and training, and fees for such services" (Yapa,1992:47). With this in mind, one would definitely consider GIS to be inappropriate technology in the more rural areas of Africa. In the urban areas however, the possibilities for adoption of the technology are stronger. Successful implementation and utilization is evident in the ever increasing number of digital mapping projects in Africa.

2.5 Is GIS appropriate technology for Africa?

The developing world has been steeped in a debt crisis since the 1970s. Today, according to Yapa (1992) a large proportion of export earnings are spent trying to repay the interest that has built up on the debt leaving little money for regional development projects. The effect of this on the lives of those leading a marginal subsistence has been considerable. On a continent where in many areas a significant proportion of the population still do not have access to a clean water supply, food, health facilities, shelter or education and basic survival is a daily goal, the idea of pouring millions into computer hardware and software does not seem just. One needs to question whether information technologies are appropriate in Africa. Of what use to people who are struggling to survive, is a digital national atlas?

The idea of technology playing a crucial role in the economic development of developing countries has been a topic of discussion since the early 1960s (Yapa,1992). E.F. Schumacher produced the idea of providing an intermediate technology that would be "very much simpler, cheaper and easier to understand and maintain than the sophisticated, high technology of the West" (Yapa,1992:42). Although the idea is attractive, in reality, it has been slow to take off.

'Appropriate Technology' (AT) has become a buzz word when talking about advancing development in third world countries. Yapa (1991) describes these technologies in a similar fashion to Schumacher as "low in capital costs; they can be maintained without a high level of expertise; and they do not involve patents, expensive copyrights and royalties" (Yapa,1991:41).

Additional criteria associated with appropriate technology include the ability to locally manufacture products through the use of local materials and expertise. The technology is considered by Yapa (1991) to be simply understood and controllable at village level. AT is envisioned to create jobs, allow community decision making, rely on renewable energy such as solar or wind power, be flexible to change and have no attached royalty conditions thereby ensuring no future payments. Considering a GIS such as PC ARC/INFO within this framework might lead one to believe that GIS has little relevance to the ideals associated with appropriate technology. On the other hand, once the initial costs have been covered, it is suggested by Yapa (1992) that GIS could become cost effective and complement the ideals of AT in that these systems can be used to identify local resources (Yapa,1992).

Development projects in Africa are becoming more and more focussed around locally available resources with the hope of achieving self-reliance. It has been established by Yapa (1991) that uncovering exactly what these local resources are takes a great deal of intensive research. It has become apparent that the information-intensive research requirements might justify the utilisation of GIS technology to some extent. It is suggested that "GIS is not simply a tool for 'mapping' resources that are self evident, but is an instrument for discovering local resources contextually" (Yapa,1991:52). Combinations of data sets may provide the

user with information which was never expected. There is the possibility that GIS could provide information which would nullify the drawbacks of equipment costs, training costs and consultation fees. If GIS can fulfill these expectations, putting the appropriateness of the technology under question may not be necessary. Once cost efficacy has been reached, GIS can then be measured for its appropriateness along cultural, social and economic grounds perhaps justifying its adoption in the developing world context.

In local development initiatives requests are often made for computer hardware and software with the capability for database management and word processing. By the end of the 1980s the Botswanan government realised its need to adopt more effective management systems to improve communication between its various departmental levels and search for a more efficient means of retrieving and disseminating information (Mogae, 1993). By 1993, the computer systems which had been developed were expected to help the government ensure greater efficiency in resource utilization, improvements in general services to the public, greater efficiency in revenue collection and increased control over the government budget (Mogae, 1993). In his opening address at a conference on Information Technology utilization in developing countries, Mogae said "we, in Botswana, are in the process of embracing that technology, and are only beginning to learn about its cost and benefits" (Mogae, 1993:ix). According to Yapa (1992), requests from planning offices in local areas have extended from database management systems and word processing to automated map production, map analysis and GIS capabilities.

Data availability in Africa is particularly poor and "the lack of data is one of the biggest stumbling blocks when implementing a GIS" (Stadler, 1997(a):18). Bassole (1998) notes that a lot of data relating to African countries can still be found in Europe. Aerial photographs for example can be found in the mapping archives of the former colonizing countries. Even when spatial data has been captured, there is very little data sharing between organizations in Africa. As a result of this much data capture work is duplicated, emphasising the need for a national database. Van Rensburg and Dickinson (1992) suggest that the key to success of GIS lies in the establishment of a flow of information between departments with a possible future vision of a global database network.

Ghana is described as suffering from "an information drought" (Fry, 1998(a):27). A population census has not been carried out in the capital city since 1984 when the population was set at 1.7 million. The mayor indicates that he thinks this figure is more like 3 million. The absence of cadastral data is reported by Fry (1998(a)) as hampering the work of builders and engineers who have no central location to turn to for infrastructural plans of the city. The effects of this lack of information will undoubtedly be reflected socially and economically. In situations where there is a severe lack of data, "GIS is a non-starter" (Fry, 1998(a):27). In an attempt to rectify this data deficit, the country is on a path to data collection. Once captured, the data can serve as a platform from which future work will be carried out. The type of data that needs to be captured should not only relate to the city dweller. In the eighties, Savane (1984) stressed the importance of providing relevant information to people at village level. This is a point which needs consideration today and if taken seriously, would go a long way towards justifying the use of such technology in Africa.

ALCOM, the Aquatic resource management program for Local Communities is an example of a database which is adapting to the African environment; it could help classify GIS as an appropriate technology in Africa. Fish species data relating to Malawi, Tanzania, Zimbabwe, Zambia, Lesotho, South Africa and Swaziland are being fed into a huge database. Data for Angola and Swaziland was noted by Verheust (1998) as being extremely limited. The results of the research are available on the Internet as well as on CD-ROM where "clickable maps allow fast queries to the Surface Waterbody Database" (Verheust, 1998:pers.comm.). Due to the expense of GIS software such as PC ARC/INFO and IDRISI, and the expense of training manpower to operate the systems, the simplest system is used. WINDISP, a free program developed by the FAO, is used for digitizing. MapViewer is used for mapping in addition to a Lotus approach to custom written software. It was noted by Verheust (1998) that there is the real risk of training people to use PC ARC/INFO and ArcView and then losing them to the private sector.

There is little doubt that the success of a GIS also hinges on the experience of the user, and the ability of African countries to provide a skilled workforce will play a role in determining the appropriateness of GIS in Africa. Woods (1993) notes that the business sector tends to spend large amounts of money on training its personnel, and it has been suggested that this sector should support the programmes that are

run in schools and universities to improve the skills base. "A utility able to deliver information and customized learning materials wherever and whenever needed is of interest to every organization with large educational and training responsibilities" (Woods,1993:89). Van Rensburg and Dickinson (1992) support the call for operators having an in depth understanding of the capability of the system in front of them.

Yapa (1992) describes technologies designed for conditions of capital availability and scarce labour, which continue to be bought by African countries. The main reasons for this is that Western companies are not developing intermediate technologies and understandably want to sell the products that they already have. Many developing countries spurn the idea of intermediate technology as it has the attached stigma of being inferior to the more 'high tech' equivalents. Stadler (1997(a):18) suggests that "The success of GIS in Africa is not through Europe. The future for GIS in Africa will come from South Africa and not from anywhere else". Perhaps a more locally based GIS industry in South Africa could indeed supply African countries with more affordable, locally relevant software and hardware, setting GIS into a more appropriate framework in the African context.

2.6 Digital mapping projects and databases in Africa

Africa South of the Sahara has been described as "a region full of contrasts: from pockets of first world development to areas of social and economic devastation" (Stadler,1997(b):12). This description could well be applied to the entire African continent. Ironically, salvation for the poorer areas may in fact lie in these so-called 'pockets of first world development'. It is in these areas that developments in IT are increasingly being relied upon to help achieve economic and social upliftment in the poorer areas. More specifically, GIS is playing an increasingly important role in managing local resources and improving decision making in government departments. Looking at the results of projects which have actually made use of GIS technology, may go a long way to establishing whether or not GIS has a role to play in Africa.

In this section, examples of digital mapping activity in a selection of African countries will be outlined. The examples given should serve as an illustration of the type of work which appears to be achieving success in the African context. This is not an exhaustive review. A discussion of digital atlas work in Africa will

be made in the following section.

2.6.1 Botswana

In a study carried out in the early 1990s by Nkambwe and Arnberg, (1995) concerning data flow for analysing land use competition in the Batlokwa tribal area in Botswana, several pertinent issues arose with regards to GIS utilization. A number of organizations, both governmental and private needed access to the same data for a range of applications. GIS was chosen as the means for improving the data flow between organizations and departments.

In the tribal territories of Botswana, records of land ownership and land use relied on community recollections and poorly run land boards. Increasing pressure on the land in the Batlokwa tribal area, called for a more organized means of recording land ownership and use. The land board of Batlokwa tribal area had three sets of uncoordinated land data relating to residential, arable and grazing land use for certain zones. The data was incomplete and was not used to draw up any land use guidelines. As a result of this, control over the use of land was almost non existent. The tribal chiefs although important members of the community, were not given any access to land use data and as a result, viewed any government officials with suspicion. Although land officers were working on different aspects of land use in the area, they all indicated that they would do their jobs better if they had access to all the data pertaining to land use in the area (Nkambwe and Arnberg, 1995). An ARC/INFO database containing 20 layers was developed allowing all officers access to the same data thereby attaining the potential of GIS to "tear down the walls that heretofore separated those departments and to create one model of the real world so that decision making and control [could] take place" (Nale,1992:52). The GIS in addition to this, has improved access to a wider informationbase. The graphic abilities have made decision making easier and the ability to update information with facility has been greatly appreciated. The most important benefit however, has been "the possibility to improve and integrate relationships among scientists in the field and those decision makers who can be classified among the potential users of the system" (Nkambwe and Arnberg,1995:119).

The use of GIS in land use management is just one example to be found in Botswana. A more recent

example can be found in the activities of the Department of Water Affairs. This department has made use of GIS to help monitor the consumption of water and record consumer patterns. The integrated information system has pinpointed areas of inefficiency and allowed for huge monetary savings (Stadler, 1997(c)).

2.6.2 Ghana

According to Mensah and Nyamekye (1998), road departments hold a multitude of spatial data which could be used more effectively in planning. However, in Africa "due to the high cost of using traditional map-making techniques for updating spatial data" (Mensah et. al., 1998), gathering and managing this type of data is severely lacking. The latest available road map used by the road departments in Ghana was produced at a scale of 1:50 000 by the Surveyor General's Office in 1973. Due to the lack of up-to-date information, the Department of Feeder Roads is inefficient in its maintenance of the country's roads.

Developments in remote sensing and Global Positioning Systems (GPS) technology are highlighted by Mensah and Nyamekye (1998) as a means through which spatial data could be updated cost-effectively. A pilot study of the use of these technologies was carried out by the Remote Sensing Applications Unit in the capital city, Accra. Roads which were not visible on the remotely sensed images were located with the use of GPS. At the culmination of the project, 216 km of roads unrecorded on the traditional paper maps, were captured using GPS and GIS technologies. Through the use of desktop GIS, the database has been made accessible for use on a PC.

2.6.3 Zambia

In the capital city of Lusaka in Zambia, a problem regarding waste disposal is reported by Chirwa (1997) as having reached serious proportions. Non-hazardous solid waste has apparently been thrown along with toxic hospital waste at indiscriminate locations within the city. Budget cuts and population growth have been blamed for this breakdown in municipal services.

The Lusaka City Council had recognised the seriousness of the situation in 1995 when they investigated the use of GIS to locate the best sites for burying the problem waste. Using a list of criteria related to

water bodies, transport areas, residential zones and geology, the most suitable sites were pinpointed. Chirwa (1997) reports that the pilot study took a total of two months to complete. The project was at the time the article was written, going into a second phase where additional criteria were being entered into the GIS to help formulate a proposal "of waste management scenarios, based on their estimates of Lusaka's present and future waste disposal needs" (Chirwa,1997:25).

2.6.4 Zimbabwe

The Department of the Surveyor General in Zimbabwe has been working hard at developing a national spatial data infrastructure (NSDI) since 1996, which will serve as an accessible pool of information for any GIS related activity, or land planning project (Matambanadzo,1997). According to Matambanadzo (1997), Zimbabwe is at the forefront of southern African countries with regards to this type of digital automation. The cadastral records being digitised are hoped to reduce duplication of work and "improve the quality of the information and make data retrieval easier" (Matambanadzo,1997:20). Much of the NSDI relies on input from projects which are funded by foreign governments. The Zimbabwean 'blanket project' set to produce DTMs and image maps of the country for example, was funded by the French government. Mr Johan Lemarchand was involved with digital mapping, remote sensing, orthophotos and GIS applications in conjunction with the Department of the Surveyor General. He managed the production of a series of tourist image maps for the country (Lemarchand,1998:pers.comm.).

Surveyors in the country are realising the importance of the developing the NSDI and are in the process of automating their processes. Measurements made in this fashion would be a valuable contribution to the national database. Surveyors are seen as the key to greater accuracy in future GIS. They are constantly in the field making accurate measurements of land areas. "There will never be a cheaper way to get accurate data for GIS use than to capture it when a survey has been performed for another reason" (Keating,1992:34).

2.6.5 Mozambique

Towards the end of 1997, Mucumbo (1997) reported that there was interest expressed by Mozambique in updating cadastral records. The main objective of the project, will be to create a land information

system for the entire country. The World Bank in conjunction with the Mozambican National Centre for Remote Sensing and the national mapping agency of France, have been working on a project mapping land use for the Rural Rehabilitation Programme. It is hoped that the project will provide clarity to tenure issues and land ownership. The results of this project have been printed as hard copy maps for inclusion in the National, Provincial and District Cadastral Atlas with the data kept in digital format awaiting inclusion into the main GIS program (Mucombo,1997).

2.6.6 South Africa

GIS has found its niche in South Africa, being used in township planning, mapping of malaria, security monitoring, and game tracking to mention a few. In a township called Atridgeville, a GIS has been set up to provide the community, the emergency services and shop owners with information. It has been noted that "one of the problems with GIS is that it is often too complicated in the development context" (Reporter,1997:10). In this example however, the system has been simplified in a bid to make it easier to use. The Graphical User Interface (GUI) has been simplified with only the relevant tool buttons remaining and the user interface is displayed in four possible local languages to aid understanding. The simplified screen and choice of local language has reduced the time that would otherwise be required for training.

The information available includes a base map indicating spaza shops, tuck shops and general dealers (Reporter,1997:10). A spaza shop is a South African term which refers to a type of local café in which one would find a limited number, but a wide variety, of goods from soap and toothpaste to vegetables and sweets. The visual representation of these shops and general dealers is expected to be fairly familiar to local people and may provide access to local input with regards to information. People who are illiterate hold valuable local knowledge which if tapped, would enrich the information system (Reporter,1997).

In two other examples the diversity of GIS use in the country becomes clearer. Fry (1997) writes that GIS has been used to map the geographic spread of students registered at the University of South Africa. The driving force behind this being the perceived need for identifying appropriate locations for

examination centres, support centres and assigning tutors to areas. In the Kruger National Park, the behaviour of male lions has been monitored using GIS according to Fry (1998(b)). The project has apparently given new insight into the hunting habits of the male lion to interested parties. It took two years to collect the relevant ecological data such as rivers, water holes, vegetation etc. along with data related to different animals.

Malaria is a disease which has gripped the people of Africa for years. Reported by Stadler (1998(a)), a database is being built to map the occurrence of the disease for the first time. The project is apparently expected to be completed in 2000 with the production of an Atlas of Malaria in Africa. The GIS application is particularly good at assessing seasonal occurrence of the disease. Within fifteen years, the project is expected to be established enough to be able to effect a significant impact on the spread of malaria on the continent (Stadler,1998(a)).

In the rural areas of the country, farmers are being forced to adopt more effective security systems. GIS is being used to map information such as farm boundaries and farmers names. In the case of an alarm being triggered, the farm in distress is immediately viewed on screen. In time it is hoped that the information fed into the database could also be used as a management tool for the farm (Reporter,1998(a)).

It is suggested that the "absence of a common national data set is one of the stumbling blocks to the growth of effective GIS in public and private sectors" (Stadler,1998(b):34). The work being carried on behalf of the South African government for the 1999 elections could go a long way towards contributing to a national database that could "provide a sound spring board for future developments" (Stadler,1998(b):34). The level of detail being collected by field workers is considerable. Features such as availability of transport, electricity or telephones are recorded by field workers in villages. The data produced will ultimately be sold at a cost set by the Treasury depending on the nature of the user.

2.6.7 Swaziland

In June of this year (1998), a cadastral database project covering the entire country of Swaziland, was

completed. The project was sponsored by the United Kingdom's Department for International Development (DFID) and provided ESCOM, the Mbabane City Council, the Water Services Corporation of Swaziland and a Johannesburg consultancy firm with portions of raw data. The data indicates all land divisions and holds information that would otherwise have to be looked up in the cadastral files kept in the Department of Works (Johnson,1998:pers,comm.). An example of the type of information that is included would be rights of subdivision of the land. In July, the DFID donated six computers to start off a digital mapping project which it is hoped will ultimately provide digital data for the entire country.

A risk mapping project was undertaken in the country at the end of 1997, funded by the European Union. The aim has been too improve the identification of areas and sectors of the population who are vulnerable to drought. The computer software Risk Map was developed by SCF-UK. Three field workers were trained over several days, to collect information and familiarise themselves with the software. Ultimately, it was hoped that a map identifying food economy zones would be produced and overlaid with an administrative map of the country. With this overlay, identification of vulnerable populations would be possible (Holt,1998).

2.7 Learning from applications in the developed world

In the United Kingdom, according to Wain (1997), GIS has a significant role to play in the National Health Service. The health industry has a wealth of spatial data which when collated has the ability to be extremely useful; it is hoped that the database will be able to detect the incidence of disease early in life and relate it to lifestyle habits. Presently, service provision and its quality is monitored through the use of the technology. Studies such as these could draw their basic data such as road networks from a national archive substantially decreasing their overheads during data capture. Service provision in the form of access to doctors and family planning is a significant area in which Africa could make use of these technologies.

In 1993, Simkowitz (1993) reported on the use of desktop GIS in traffic analysis zones by the United States Census Bureau, using graphics on their computer screens "not on maps pasted to office walls"

(Simkowitz,1993:38). Additional information layers have apparently been added to the database to enhance transportation planning. The GIS is being extended to applications including identification of major accident zones on the country's roads, assessing access to public transport for people and designing more efficient bus routes. Public transport could be improved in many African countries if a database such as this was available and planners knew how to manipulate it. It is however one application which might not hold as much urgency as others.

Writing from the Gulf state of Qatar, a country in the Persian Gulf, Lang (1994) reported on a situation being experienced where a lack of coordination of departments resulted in seventeen agencies updating the same base maps. Having identified this, a central mapping agency was appointed for updating maps. This not only ensured an elimination of work duplication, but also ensured that mapping standards were uniform. There is little doubt that African countries need to improve the data they have of their territories and such a project would be welcome. Within four years, a national digital map database was completed in Qatar and is "available to all government ministries across a high-speed network and serves as a foundation for public access to many map products" (Lang,1994:44). The design of the system was carried out using input from each director in the government. The ARC/INFO and ORACLE software adopted for the project were translated into Arabic and data was made available in read only format across the network. The data was to be made available to other government agencies. Mapping products useful to the public in general and to organizations, have been developed. Such products include an electronic place finder, street network data for taxi, fast food and a range of other delivery companies, and an automated map production system. People may well have access to free standing kiosks in the future, in order to tap the information (Lang,1994). The centralised database also provides the basis for an education project where CD-ROM products are used to increase the geographical awareness of the country.

In the United States there has been a definite trend towards the marketing of pre-packaged databases which are easily integrated into GIS programs (Parent,1992). These data sets include covers such as business point location data, crime statistics and education at city or county scale. This type of readily available information according to Parent (1992) has provided a significant number of people with

information. In an African context there may not be such a ready market for this type of product due to its cost. National archives of digital data in African countries should ultimately aim at providing users with this sort of data. If necessary a nominal standardised fee could be charged.

Remote sensing was identified at the Rio De Janeiro 'Earth Summit' in 1992, as "a source of information to build up a global environmental database" (White,1994:295). Examples are given by White (1994) of remotely sensed images providing detailed information on features such as oil slicks, air pollution, deforestation, as well as providing the ability to monitor ozone depletion levels and effects of disturbances on the environment such as the Gulf War. Burning of the veld in Swaziland has become a yearly ritual despite pleas from conservationists and government to refrain from starting fires. Believed to encourage the growth of nutrient rich grass, cattle owners often ignore the pleas. If the results of a study on the effects of fire on the land were conclusive, the results could be shown to the rural cattle owners, making full use of visualization capabilities. Forecasting the effects if burning continues, could be made apparent. In a graphic format, the possibility of misunderstanding through language barriers or illiteracy, would be reduced.

According to Mortimer (1992), English Nature, an organisation set up in the interest of preserving and promoting England's natural heritage, has made use of GIS with integrated remote sensing since 1988. The kind of data collected and stored includes point data for the major habitat locations, species distributions and boundaries captured from remotely sensed data, aerial photography and paper maps. An additional use of remotely sensed data has been outlined as being used as backdrops to topographic map data. The distances are so vast in Africa, that if cost-effective remote sensing could be used to capture data on these areas thereby improving data availability.

According to Barnes (1992) 127 million hectares of Europe fall under an 'agricultural' classification. The contribution of agriculture to an individual country's GNP varies. With the need for reliable data on productivity of all agricultural communities within the European Community (EC), this "Pilot Project for Remote Sensing Applied to Agricultural Statistics" (Barnes,1992:183) was implemented. GIS has apparently been used extensively as a means to predict crop yield through monitoring of the crop quality;

a project which is part of a much larger vision of the Council of Ministers in the EC. In a GIS related project already mentioned for Swaziland, areas likely to suffer from a lack of food due to drought have been identified. If areas of optimum growth for certain crops could be identified, the possibility of avoiding food shortages in certain African countries, does exist.

According to Loxton (1996), whilst GIS has shown its use to local authorities in the United Kingdom, "the GIS industry is confident of the usefulness of this technology in financial industries like insurance" (Loxton,1996:8). The specific areas in the insurance industry which have been targeted for involvement in GIS are underwriting and risk management. It is estimated that 85% of insurance company data is spatial in nature and yet only 2% of it is actually utilised, "in other words business is drastically under-using a valuable resource" (Loxton,1996:8). Underwriting apparently involves the assessment of aggregated risk necessary to ensure the cover is sufficient. At Lloyds, ERAS Map is used to analyse risks such as geological hazards, property in transit and terrorism. In another application, detailed soils data collected by Cranfield University in combination with additional data is being used by underwriters to assess " how vulnerable structures are to risks" (Loxton,1996:9) such as subsidence. Loxton (1996) reminds the reader that insurers will be interested in the interpreted data set; the information rather than the raw data set.

2.8 Learning from the limitations experienced in the developed world

Countries of the developed world have the most experience when it comes to GIS applications. Assuming that these countries have mastered the use of GIS simply because they are the producers of the technology, would be entirely inaccurate. There still appear to be teething problems with the technology. Through a consideration of these problems, there may be several lessons which could be learnt by the developing world when trying to apply the same technology to their situation.

It has been suggested by Campbell (1994) that in reality we know less about the actual impact of GIS in our lives than we think. In 1992, a study was carried out on the British local government to determine the actually efficacy of GIS. British local government was identified as one of the most significant users of the technology.

The results of the study showed that many systems were underutilised with applications focussing on one particular department's needs. Most departments used GIS for automated mapping functions neglecting any complex analysis - a similar pattern was revealed in Swaziland. Due mainly to a lack of skilled people, GIS is used to produce land use maps with no analysis being carried out (Van Waveren, 1998: pers. comm.). Because of the time it takes to capture data and fully understand the capabilities of the system, most departments according to Campbell (1994) had felt little impact from their GIS. It was realised that to benefit fully from GIS, the system had to be implemented over a period of time taking care to cover three conditions. Firstly, the resources of the Department have to be taken into account when outlining the end user requirements. After all, a "technically elegant system is of little value if it produces information nobody wants" (Campbell, 1994: 316). Secondly, a commitment to the project is needed from all levels of the Department. To achieve this, all staff need to have a say in the policy design which necessitates communication between managers, computer specialists and users. The introduction of GIS was found to cause instability with people unwilling to adapt to change unless the benefits were clear. Change can be seen as a threat rather than an opportunity. Securing the support at all levels provides the third essential condition, of organization and stability in the workplace. Peel (1997) considers the gaining of support from the people within an organisation to be important to the success of a project. The benefits of a GIS are often only apparent after the full system has been developed and considering the time and cost this requires scepticism is likely to develop. Peel (1997) adds that once the system is functional, its continued use is dependant on maintaining and updating the database.

Campbell (1994) noted that data sharing was seen to be severely lacking in her case studies of British local government departments. This is a problem common in Africa as well. The data produced in one department was not considered to be significant enough to warrant access from outside interests. The only data sets in demand, were automated maps from the Ordnance Survey and their census data. The necessity for pooling information whether or not one thinks it may be useful, is necessary. If information is not accessible, there is the real danger of data duplication wasting valuable time and money. "While the advantage of GIS must be self-evident to users the complexity and sophistication of the technology must be virtually invisible" (Campbell, 1994: 317). Conditions for GIS installation and use need careful consideration to ensure it does not end up on the rubbish heap of technological obscurity. Likewise,

African countries really need to weigh up their reasons for adopting this technology.

With regards to data acquisition, Peel (1997) highlights the fact that cultural barriers between different departments can cause delays. When permission for access is granted, legal conditions attached to use of the data can slow data processing down. Much attribute data has to be retrieved from paper files, which is tedious and time consuming as some data is 'lost' in the system, with no one quite sure where to begin looking for it.

The need to have a GIS professional with good communication skills, heading the team was emphasised by the Sedgemoor District Council in the United Kingdom. This district council aimed to build a corporate GIS within two years; a goal which was unrealistic. "Even with all the necessary technical knowledge and experience, nothing can quite prepare you for the complexities of implementing GIS in such a diverse organisation" (Peel, 1997:19). Statements such as these are worrying in the case of a developing country where expertise can be at a premium. Whilst there is a GIS specialist in the Ministry of Agriculture in Mbabane, Swaziland, he would be unable to head a full GIS program in his department without a trained team behind him.

According to a report written by Davidson, et.al., (1994), GIS technology has had an increasingly important role to play in rural based land use development projects in the developed world. The primary uses for these information systems outlined in the report, were policy production in land use, environmental impact assessments, retail planning, and monitoring of landscape change. Several development proposals have been assessed through full utilization of the visualization facilities of digital terrain models available for use within GIS (Davidson et.al., 1994). The time taken and cost involved in data input however, has been highlighted in the report as a major drawback in the routine usage of GIS. If too costly for developed countries to use, the sustained use of similar technology in the African context is unlikely to be a realistic goal. A national archive of information given time to grow might in time however reduce the amount of data needing to be captured in a digital format. National digital atlases could act as archives, or the basis of a national database from which developers could obtain portions of their required data set.

2.9 Factors to consider when working with GIS related projects; accuracy issues

An appreciation of the inaccuracies inherent in GIS related projects is essential to ensure a balanced overview to the reader. "Consider the "perfect" GIS world of the future. The base map would be accurate and geodetically correct. The data would be available in compatible forms and formats. The GIS would be maintained and current. Information from state boundaries to 3-D models of grocery stores would be included. That is the future. Where are we now? Consider the base map and how accurate it is" (Keating,1992:32).

According to Calkins (1990), organizations and companies have been capturing data for the creation of digital databases for over 25 years. The ever increasing utilization of digital mapping and computerized analysis has required the conversion of data into a computer compatible format through a variety of processes. Dangermond (1990) encourages the consideration of the training, the man hours, the energy and the effort put into successful data capture, as a pathway to understanding that the most expensive part of a GIS could well be the digital data which is created to use with the system. Despite the time and costs associated with data capture, there is often limited attention given to the actual quality of the end product. Whilst "most data gathering disciplines treat error as an embarrassing issue to be expunged, the error inherent in spatial data deserves closer attention and public understanding" (Chrisman,1991:165).

There are several possible sources which could provide a GIS with compatible digital information, some of which are likely to hold considerable error. "Cartographic generalization...can affect locational accuracy to a great extent. Features may be displaced and their original shape may be distorted" (Muller,1991). Computer Aided Drafting systems capture electronic maps which can be integrated into a GIS. In this case the user relies on the level of accuracy decided upon by the producer of that information. This became apparent in the use of digital maps obtained from the Ministry of Agriculture in Swaziland. These maps have been captured from the 1:250 000 topographic map of the country and when overlayed with coverages captured from 1:50 000 maps of the country, a considerable discrepancy between the two international borders exists; km.

The majority of spatial data, especially in the African situation, exists in paper map form. Digitizing, scanning or photogrammetry can be used to capture data from these paper maps in a vector (line) format with links to related spatial and non-spatial attribute data. Dangermond (1990) notes that inaccuracies in the base maps may be repeated in the resulting digital product. Image processing systems such as remote sensing and satellite imagery are able to capture image data in a raster format providing an accurate data source where error can be introduced only through incorrect analysis.

Very little digital data of African territories exists and as a result of this, African countries utilizing some sort of GIS system are often forced to begin data capture from scratch using manual digitizing or scanning. Most of this cartographic data capture is carried out by manually digitizing available traditional paper maps. Manual digitizing appears to suit the African environment as it offers "low capital cost, low-cost labour and great flexibility and adaptability" (Dangermond, 1990:223). Although modern software capabilities ensure that some errors are identified in the digitizing process, flawless digitizing is not possible. Manual digitizing can introduce positional errors into a database which the user should be made aware of.

The susceptibility to swelling or shrinkage of the medium from which the data is being digitized can determine how much error is introduced into the digital product. An expansion of 2mm on the map could mean a difference of metres on the ground. Creasing of the base map during digitizing will also affect the level of accuracy attainable. Editing the coverage, for example moving nodes which have not snapped together, also introduces a margin of error.

The source maps used in data capture have often been compiled by different draughtsmen at different times, and to varying levels of accuracy. "The map as a communication medium involves the use of processes such as selection, classification, displacement, symbolisation and graphic exaggeration" (Cassettari, 1993:24). Digitizing repeats these characteristics possibly augmenting any existing exaggeration.

Capturing obsolete data is unavoidable in some cases. Paper maps are static in nature in that they

represent the data that was present at time of production. Additional fieldwork could be the only way to update these maps. Human error is unavoidable in manual digitizing. Mistakes in the digitizing of lines are inevitable especially if the operator is disturbed or his/her concentration falters during the process.

Scanning base maps offers an opportunity to capture data from a base map automatically. Although "translation of the most complex map into digital form via the scanner represents no special problem,...intelligent identification of the cartographic elements present in the drawing will require very high skills on the part of the software designers" (Peuquet,et.al.,1990:216). Traditional paper maps consist of a mixture of line, area and point data as well as text. Line data on paper maps often differs in width and style (for example a dashed line indicating a district boundary and a solid line representing a road), lines often cross or meet and some features are differentiated with the use of colour. The best document used for scanning would be one that holds uniform line widths and is mostly error free from the start. Editing scanned documents can be so time consuming and expensive "that it may well be better to use manual digitization, with the operator using his intelligence to select line endpoints directly, and to select intermediate points to specify simple curves" (Peuquet,et.al.,1990:221). The expense of scanning base maps may preclude African users from using the technology.

Accuracy achieved by manual digitizing is deemed acceptable by planners, but if this accuracy could be increased without putting the cost of GIS out of reach, the option should be considered. Depending on the user, map accuracy requirements alter dramatically. Map scale requirements have been divided into four broad categories by Nale (1992) from engineering design, engineering planning, general planning to regional planning with the level of accuracy required decreasing. Before data capture begins, the operator has to consider levels of accuracy and precision. Accuracy in this case is divided into two categories, namely detail and location. Looking at a map the level of detail refers to the depiction of real world objects. For example the operator might ask whether all school buildings are depicted on the map and whether or not they are geographically correct in their location on the map (Nale,1992). The level of accuracy on the base map will determine the completeness of the database once the data has been entered into the computer. If the database is going to be used to maintain municipal services, graphic precision is necessary. For example the operator will need to be able to visualize the proximity of

pipelines to driveways or sidewalks. The precision required depends entirely on what the user needs (Nale,1992). In the production of national digital atlases, it is imperative that a statement on the level of accuracy of the product is made, so that subsequent users understand the data that they are using without expecting results beyond the capacity of the product.

It is suggested that maps created without geodetic precision may be no more useful than visual representations. The greater the geodetic accuracy that is built into a GIS, the more useful it will be (Keating,1992). "Why? Because unless they fit mathematically in the computer, you never will be able to do anything more than simply view the graphics on a computer screen" (Nale,1992:52). The analytical power inherent in fully fledged GIS will not be used to its potential. It is suggested that "compromising map standards (land base detail and accuracy) will compromise your GIS applications" (Nale,1992:53). Capturing data to such a high level of accuracy and precision is however extremely expensive.

The amount of money that has been fed into commercial and industrial developments of digital technology far surpasses anything that has come the way of social applications (Woods,1993). The uses of GIS for interactive learning, management and planning are endless, especially in systems designed for public use (Woods,1993). It has been suggested that in the past, "computer and telecommunications technologies have primarily functioned to enhance the wealth, power and control of large corporations, the government and the military" (Downing, et.al.,1991:1). It is time to realise the potential benefits of information systems and in particular GIS in the sectors of education, health, tourism, resource management, census mapping, land use planning and information dissemination. In this capacity, IT could play an important role at grass roots level, benefiting a much wider user base than ever before.

2.10 The benefits of cartographic data display

GIS has been credited by Bishop (1994) as a means for converting raw data into information which is meaningful to every user, whether a scientist, a curious member of the public or a land use planner. This has been achieved through the use of graphic display.

Human understanding "is essentially spatial in character and making things 'visible in the mind' has been

a key to many, if not all, major scientific discoveries" (Wood,1994:10). Graphic representation of data according to Petch (1994) has a greater impact on a person's memory, provides quicker understanding of spatial relationships at hand and allows greater efficiency in problem solving. Humans tend to visualize their knowledge and use images in their thought processes. Visualization produces an environment which humans are familiar with providing access "to spatial patterns that are not readily accommodated by the naked eye" (Buttenfield and Mackaness,1991:429). Graphic representation in the opinion of Medyckyj-Scott (1994), might include 2D and 3D maps, tables, images, graphs and charts whilst Petch (1994) insists that representation could extend to virtual reality where a 'fly over' of Madagascar after years of deforestation for example may communicate the problems across more clearly than a set of graphs or statistics might.

In the GIS environment interacting with spatial data is taken to a new level. Although the ability to pan and zoom in the map is in most cases never faster than the movement of the human eye, Woods (1993) notes that the user will not experience the map boundary as he would when using a traditional paper map. If the user understands the nature of the information held in the database, he will be able to explore the environment to its full potential. Digital maps allow the user greater control over the amount of detail he wants to use. The more experienced person may be able to deal with a greater density of information in front of him. The digital environment allows for this extent of flexibility.

Due to the need for spatial awareness and a measure of map and computer literacy, the ability to work with and understand "geographic information is a privilege of the educated and informed few" (Pateni,1997:16). The graphic capabilities of GIS hold the potential to have a significant impact on interactive education in South Africa and other African countries. In general map literacy in South Africa is thought by Pateni (1997) to be very low and considering the number of people who do not have access to computer facilities, computer literacy is likely to be low as well. In an effort to counteract this problem in Cape Town, a project was started by the Chief Directorate of Surveys and Land Information of that city in 1997. The aim was to uplift disadvantaged children through a map awareness and literacy programme. If more projects like this one are implemented, South Africa's children may be equipped with the tools needed to understand and manage their environments as geographic information becomes

available to all.

The benefits of GIS have reached a wider user base in India. The country has a large resource base of trained software producers who have been able to design software which "is based on the villagers' perceptions of their needs" (Woods,193:95). Much of the software does not require the user to be literate. The government had aimed to create a national network to help in rural planning projects, health matters, water monitoring and literacy. The project developed into an 'Informatics for Community Use' making India the first country to achieve such a project according to Woods (1993). Using GIS mapping capabilities, agricultural recommendations for a village could be described in graphic form, thereby bypassing the problem of illiteracy. There is no reason why this software could not be adapted to the needs of rural Africans.

The increasing use of GIS in the public and private domains, is resulting in the generation of large amounts of spatially referenced data. Raveneau et.al.,(1991) note that this data should not be reserved for the use of specialists, but should be made available to the non-professional public. Often the data is underutilised due a lack of processing of the data and poor methods of communication (Raveneau et.al., 1991). Many municipalities have valuable geographic data sets of general interest. The majority of the data sets however are in formats which are incompatible with the majority of users. There has been a call for "the transformation of spatial data contained in computer banks into significant spatial information, and for the diffusion of that information by means of attractive and efficient visual displays. The electronic atlas is one of the possible solutions" (Raveneau,1991:201). National digital atlases for African countries could then be used as archives of information to be applied to not only to health issues, education and land planning, but also to tourism, resource management, census management and information dissemination.

2.11 The Digital (electronic) Atlas

"In steadily increasing numbers, geographers, scientists, students, politicians, the general public, are drawing upon the vast resources contained in maps and atlases" (Boggs,1959:preface). Boggs wrote this in 1959, referring to the traditional paper atlas. Taken out of context, this statement could easily be seen to be referring to digital mapping projects and atlases. Coppock and Rhind (1991) suggest that whilst

the development of GIS has come from a variety of initiatives, they highlight the experiences of the publication of the Atlas of Great Britain and Northern Ireland in 1963 as being significant in the development of a digital approach. The atlas was criticised for being outdated and unwieldy to use. Between 1958 and 1960, D.P Bickmore, one of the publishers became convinced "that only the computer could provide a cost-effective mechanism to check, edit and classify data, to model situations and to facilitate experiments in graphic display" (Coppock and Rhind,1991). Considering the range of capabilities available in digital atlases today, Bickmore certainly made a pertinent point.

According to Slocum and Egbert (1991), the capabilities of atlas products do vary, from the user being able to call up series of maps, to interactive capabilities where the user is able to create his own maps according the data he chooses to display. The electronic atlas of Canada is cited as an example of a product that tends towards being a complete information system. The atlas allows its users to create their own maps, overlay files, query the database, and ask 'what if?' questions through simulated modelling. At the other end of the interactive scale, Slocum and Egbert (1991) mention the Electromap World atlas, which allows the user to click on countries and retrieve information relating to geography, the economy and government of that country.

Several factors have played a role in the development of electronic atlases and Slocum and Egbert (1991) outline these as follows. Significant developments made in microcomputing have produced more affordable and more powerful computing equipment than ever before, opening up access to the digital environment for a wider user base. The creation of geographic databases being carried out by an increasing number of organisations for use in areas such as land and resource management is resulting in a pool of useable information. In Canada, such data sets have been amalgamated into the National Atlas Information System (NAIS). Research on the use of geographic information in education has led to the development of instructional atlases such as the Junior Atlas of Alberta. It is suggested that the entry of geographic information into an information systems environment "has contributed to the concept of "electronic atlas" (Raveneau et.al.,1991:202).

The first electronic atlas released in the 1980s was a series of maps on the computer and according to

Perkins (1995) offered little in the way of analysis of information. Apparently some of the atlases simply reflected what one might see when looking at a paper atlas. "It is not sufficient to use the computer to reproduce on a screen what was formerly represented on conventional maps or in traditional atlases, but rather to make use of its potential for developing new methods facilitating research, communication and the acquisition of knowledge in the field of geographic information" (Raveneau et al.,1991:203).

All electronic atlases on the market in the developed world are designed to be used with immediate effect and without difficulty. Perkins (1995) notes that these atlases do of course range in complexity from view only, to complete interactivity. Atlases which exist as copies of their paper counterparts are limited in their use with the user having little or no control over the elements displayed. The more interactive atlases still contain fixed map elements, but do allow the user to zoom in and pan over the map in front of him.

The development of CD-ROM has seen more powerful electronic atlases being disseminated to a wider variety of users. Perkins (1995) adds, that the analytical functions of these atlases have extended to include overlays, distance mapping and statistical analysis. In these atlases, the user has control over map elements, one such example being the Digital Chart of the World.

Although the capabilities of digital atlases are ever expanding, their coverage of information is heavily dependant on digital data available. For countries who have extensive topographic coverage, such as Switzerland, Belgium and the United States, Perkins (1995) describes capabilities which include being able to search for street locations and specific tourist spots. In fact, "many large western cities are now covered by electronic atlases" (Perkins,1995:39). Electronic atlases have been described as the "preliminary stage to Atlas Information Systems" (Rystedt,1995:5).

Electronic atlases designed to meet navigational needs at sea and on roads, have also been developed. These atlases are part of a group of products which offer more specific coverages than interactive national atlases. Rystedt (1995) highlights some electronic atlases which have come under the spotlight at various conferences, emphasising the ability of these products to extend beyond the scope of the traditional atlas expectations. The Territorial Evolution of Canada, a Hypermedia Map apparently covers

an animation of the territorial evolution of Canada whilst the Transport Atlas of The Southern North Sea presents a cartographic model of water transportation (Rystedt,1995). Exploiting developments in multimedia, some of the more commercially orientated atlases have adopted national anthems and flags of countries to introduce viewers to their products (Perkins,1995). These atlases and the "more expensive data-rich authoritative sources of electronic mapped data" (Perkins,1995:40) will continue to be released onto the market. It is noted that the increasing amount of mapped data on the web, may limit electronic atlas sales in the future. This method of dissemination in Africa would be a positive step for countries that are unable to afford expensive software.

In a review of electronic atlases currently available, some of the positive and negative aspects of atlases on the market have been outlined by Brown (1998). 'Toposcout' developed by Maptech is described by Brown (1998) as a series of topographic maps covering the United States. Maps from the American Geological Survey have been scanned into the atlas with "the same 1956-or-so data, the well documented errors, the same minimalist legends, and the same large white borders that make reading features that cross the map edges or corners so frustrating" (Brown,1998:41). The advantages of the package are that it is reasonably priced, so it is accessible to a wide audience. People also have access on one CD-ROM to what was only available previously on 300 paper maps.

The 'Street Atlas' compiled by Delorme and Microsofts' 'Streets 98' are considered by Brown (1998) to be prime examples of the visualization attainable, as they allow the operator a bird's eye view. Using specific addresses of people, both atlases are apparently able to pinpoint the location of a house. Due to the focus of both projects however, features like rivers are not mapped in depth. The level of detail which can be included in electronic atlases is mind boggling. Maps can be linked to radio stations giving the latest updates on weather or traffic conditions for example. The new generation of digital atlases will allow the user to view maps as if flying above the ground. Microsoft's Encarta has produced a 'Virtual Globe' which Brown (1998) acknowledges as achieving this to a certain extent. Referring to traditional paper atlases in the 1950s, Boggs (1959) states that they "consist of a collection of maps made in accordance with a particular plan" (Boggs:1959:2). Whilst a digital atlas can still reflect the ideals of its traditional paper counterpart, using data stored in a GIS, geographic information can be brought to life

for thousands of people with a flexibility unattainable on paper.

2.12 Digital African atlases

In this section eight known digital African atlases will be described. The first five will be examined in greater detail in Chapter four.

i) Tourism Potential Atlas of Swaziland (Van Riet,1998)

Tibiyo Taka Ngwane is a national organisation which was set up in Swaziland by the late King Sobuza II in August 1968. It was created to invest in economic independence and self sufficiency in the country. Tibiyo is seen as an indigenous development agency with interests in all sectors of the Swazi economy (Forsyth Thompson et al.,1998). The organization contacted GIS Business Solutions in Pretoria and asked them to look at the viability of four tourism related projects around Milwane in Swaziland. An example of the type of projects that were to be looked into included the building of a cultural village and the installation of a cable car system in the area of the Milwane game reserve (Van Riet,1998:pers.comm.).

It was suggested that they could broaden the study by looking at issues such as scenic beauty creating an overall assessment of tourism potential in the kingdom (Van Riet,1998:pers.comm.). Hydrological characteristics, Vegetation, Physiography, Land Tenure, Cadastral data, Population, and conservation areas were ultimately captured and combined to produce a map of tourism potential.

ii) Environmental Potential Atlases (ENPAT) (Van Viegen et.al.,1998)

In 1994, South Africa's Department of Environment Affairs and Tourism produced a large spatial database in the form of *ENPAT* (Environmental Potential Atlases). Having seen the consequences of poor decision making all too often, the Department of Environment Affairs saw the key to successful management of the environment being access to information (Department of Environmental Affairs and Tourism (DET),1994). Information within their own department was often "widely disseminated between many different organisations, and captured on a variety of media in an even greater variety of formats which were not always compatible"(DET,1994:2-1). Access to certain information was often met with

"a 'closed shop' attitude...and it could take literally months to gain access to or acquire, certain information" (DET,1998:chapter 2). The solution to this problem lay in the development of a single database available to interested parties outside the Department as well as within. A single database, it is hoped, would "contribute to an increased awareness of environmental issues and the effects of development, and ensure that these are adequately addressed through provision of sufficient information"(DET,1994:1-1). Proof of success may be evident in the re-release of an updated version of the Atlas, which has been made available to the public from 31 August 1998.

iii) Spatial Characterization Tool (Corbett et.al.,1997)

This atlas is described as a GIS application which covers an environmental classification for research and agricultural and natural resource management for Africa, Latin America and South East Asia. The *SCT* was developed out of the need for answers of a series of queries that were posed; characterization allows a simplification of the complexities found in the environment. The African data set was released in November 1997 (Corbett,et.al.,1997).

iv) Population Atlas of Kenya (Fox,1995)

This atlas was created on PC ARC/INFO and consists of thirteen covers providing the viewer with a variety of population related information. Covers available on disk include districts, age and sex, schools, education level, literacy, tribal, provincial, urban, lakes and rivers, islands, roads, railway, and agroclimatic zones.

v) Digital National Atlas of Tanzania (Shand,1997)

In Tanzania, the Senior Cartographer at the University of Glasgow, Mike Shand has been involved in research which has covered the production of a digital cartographic database and vector maps of the country. This type of work is relatively new for Africa, and the run up to its introduction has not been smooth. Shand and Silayo (1996:1) note that although "The continent of Africa has a long history of atlas production at both regional and national levels", it is a somewhat different road travelled from that in the

developed world. In **Figures 2.1** and **2.2**, examples of maps available in the atlas, are given. The maps display the flexibility inherent in the digital mapping environment using the single regional cover to depict a variety of information.

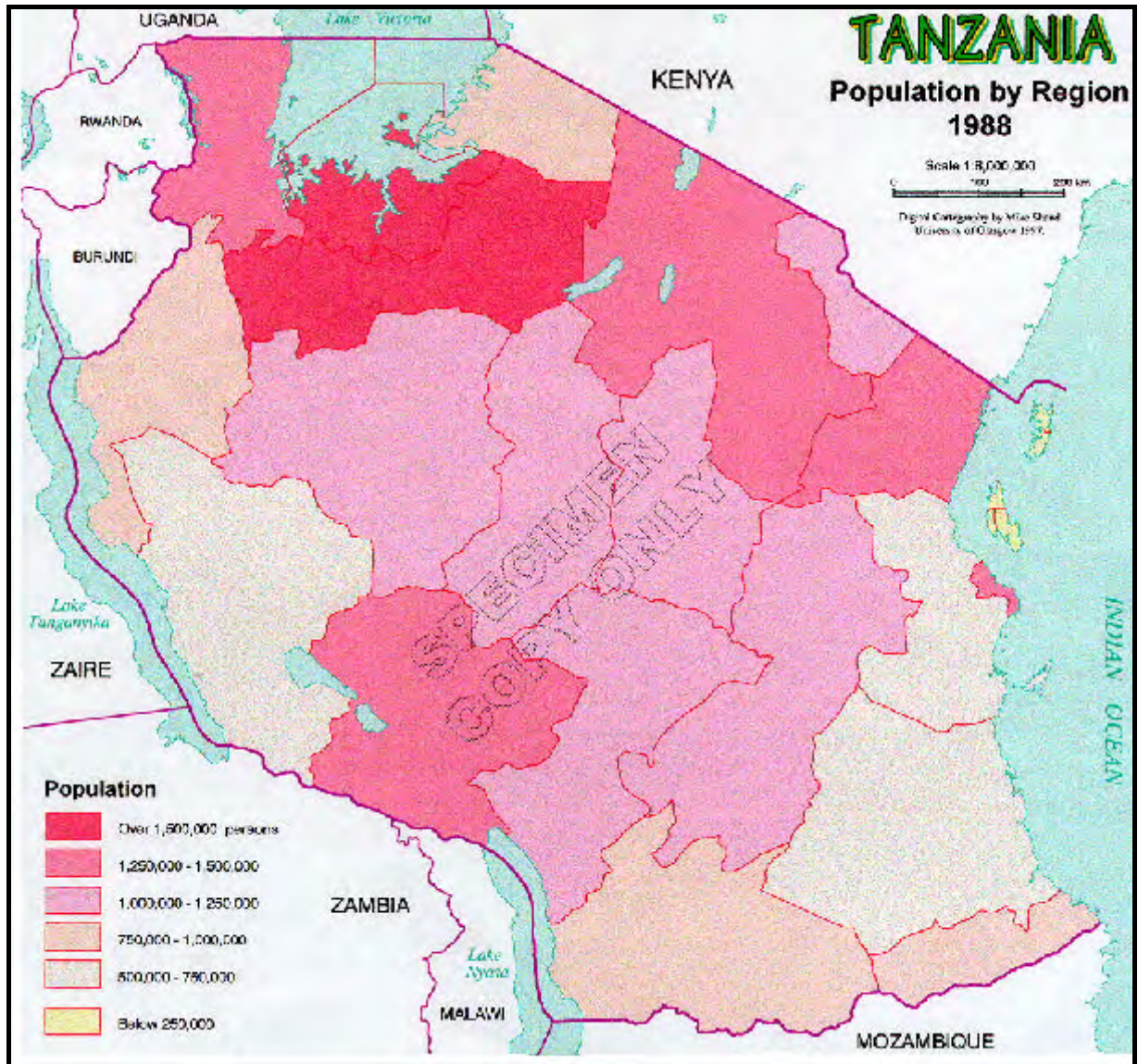
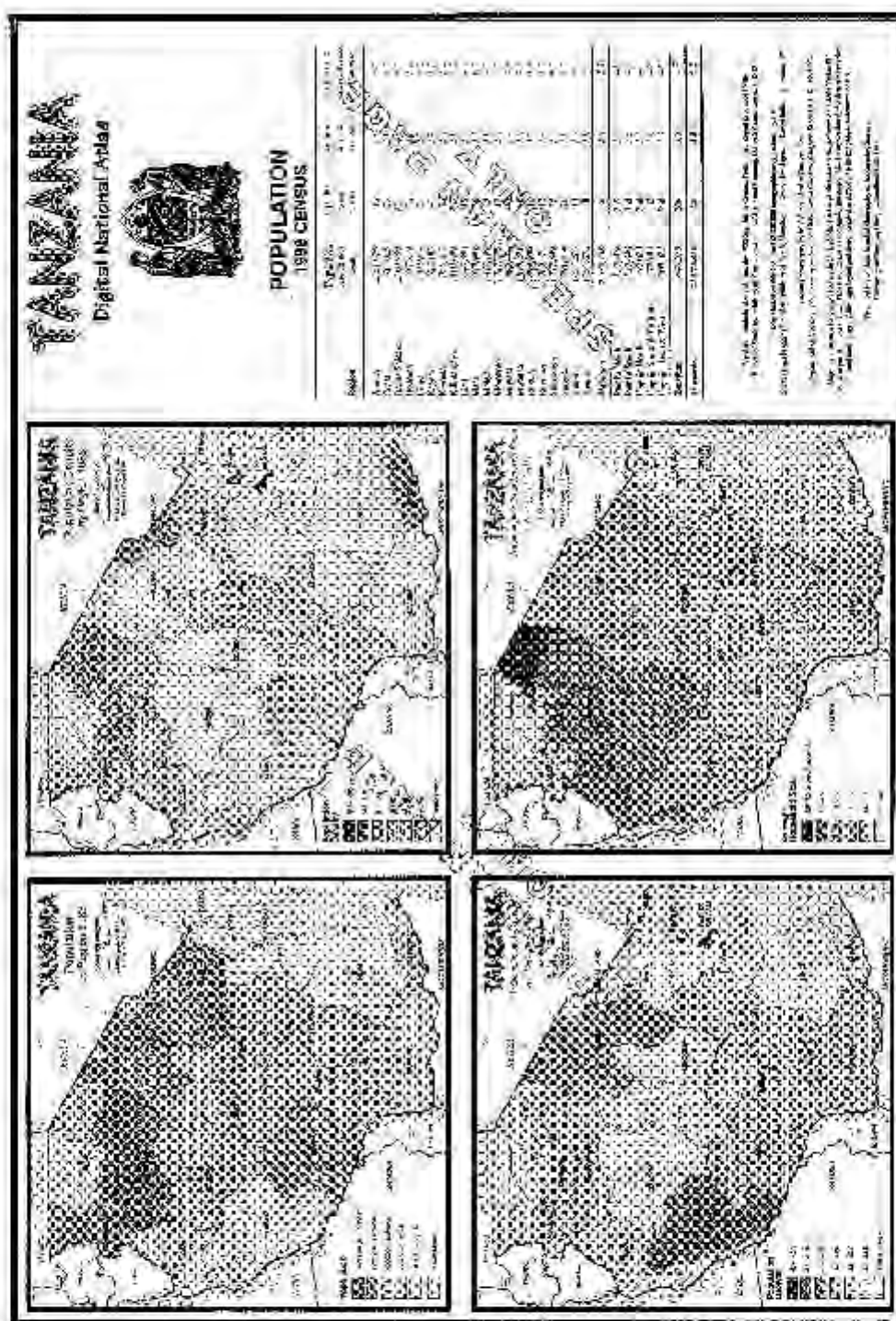


Figure 2.1: Population by Region. Sample map from the *Digital National Atlas of Tanzania* (Shand,1997)



vi) An Environmental Profile and Atlas of Caprivi (Mendelson and Roberts,1998)

This atlas has been produced by John Mendelson and Carole Roberts, funded by the Netherlands. The atlas contains 34 maps accompanied by Landsat images, photographs, text and graphs. ArcView 3.0 has been used with the Spatial Analyst extension to carry out and present map analysis. ERMMapper was used in the design and production of the maps (Shand,1998:pers.comm.).

vii) Eastern Africa Atlas of Coastal Resources: Kenya (UNEP,1998)

The United Nations Environment Programme (UNEP/GRID) has produced this atlas with the financial help of the Belgium government, the Belgium Administration for Development Co-operation (BADC) and the government of Kenya.

The atlas consists of 5 sheets captured from 1:250 000 topographic maps of the country. Landsat TM have provided land cover data with marine information being supplied by the Kenya Marine and Fisheries Research Institute; Coastal Development Service; Kenya Wildlife Service and the University of Nairobi. The resulting maps have 10 land cover classes, 10 coastline ecological classes, climatic data, cultural and recreation data, hydrology, conservation, marine and terrestrial fauna, birds, maritime transport, mineral resources and industrial data (Shand,1998:pers.comm.).

viii) Digital Agrohydrological Atlas for Southern Africa (Lynch and Schulze,1996)

This atlas is described as a "first attempt at a digital collection of maps for environmental planning in Southern Africa" (Lynch and Schulze,1996), made possible with the development of desktop GIS. It is available digitally and as a colour paper version. The atlas seeks to evaluate the effect of water availability on agricultural potential, ultimately promoting efficient water use. The producers note that they hope the atlas will be used in schools and research organizations.

Evans (1984) suggests that the emphasis which has been placed on technology has given the impression that it is "the objective of development rather than...a principle means for attaining development" (Evans,1984:25). GIS has the ability to contribute significantly to social, economic and political goals. The production of a national digital atlas in Africa should be planned with a view to attaining development

objectives. There is no doubt that GIS related projects hold the potential to solve many of Africa's planning problems; this is already evident in some of the examples given for Botswana, Ghana, Zambia, Zimbabwe, Mozambique, South Africa and Swaziland. Used to strengthen the application of cartographic knowledge, digital atlases could have a significant role to play in the African context.

The basic elements of a GIS have been outlined by Maguire (1991) as computer hardware, computer software, data and liveware. The production of a national digital atlas, requires all four. Skilled manpower is one element which may be particularly difficult to ensure. To illustrate what the production involves, the reader is taken through each step of the production process of the *Population-Environment Atlas of Swaziland*, in Chapter Three. Particular note should be taken of the numerous problems which were experienced and the time required to overcome them.

Chapter Three:

Production of the Population-Environment Atlas of Swaziland

3.1 Introduction

According to the Environmental Science Research Institute (ESRI), any project created with a Geographic Information System (GIS) requires the careful organization of a series of steps. The first step outlines the objectives of the project; the second presents the database design; the third involves building the database; the fourth assesses the capabilities of the product through analytical tasks and the final step involves presenting the results. The objectives of the thesis have already been stated in Chapter One. In this chapter, the objectives of the atlas design will be re-emphasised and steps two and three will be covered. Each stage of the production process will be outlined accompanied by problems experienced. This serves to emphasise the extent of work involved in the production of a national digital atlas. Steps three and four will be addressed in Chapter Four.

3.2 Step One - Outlining the project objectives

The main objective of this *Population-Environment Atlas of Swaziland*, is to provide support for an appraisal of the production of digital atlases in Africa. The capabilities of the atlas will be used in addition to other material, to appraise the utility of these atlases in Africa.

Designing a database to meet the requirements of the end-user is of utmost importance. The intended end-user at the start of this project was however unspecified. The Census Department in Mbabane had expressed an interest, but as the project had not been commissioned by any one group, it was hoped that the capabilities of the end product, might itself suggest the type of user that could benefit. The end product is hoped to be found useful to a variety of users "not only for special projects, but for ongoing tasks" (ESRI, 1993:3-24).

The atlas will be presented with this thesis, on CD-ROM. Examples of the covers will be included in this chapter in colour paper format. It is envisaged that the atlas will be available from a web page on the Internet subsequently.

3.3 Step Two - Designing the database

Having determined that the aim of the project was to create a digital atlas of environmental and population information for Swaziland and critically assess the process (and utility) in the context of digital atlas production in Africa, the first step was to decide which data layers were going to be captured for the atlas.

Selecting the type of data to be included and obtaining this data is often problematic. In this project, map availability was to dictate the type of data and level of detail that could be captured. Several maps were acquired from the Census Department in Mbabane. Each of them were possible source maps for capturing data. The maps consisted of a 1:250 000 topographical map of Swaziland and three sepia transparency maps; one 1:250 000 map of the 1986 enumeration areas, one 1:250 000 population density map and one 1:250 000 population distribution map.

Sepia transparency maps are originally professional hand drafted maps. The original map is passed through a machine which exposes ultra-violet light through the map onto a light sensitive film. The hand drawn lines from the original map are burnt into the film and a sepia transparency is created (Tweedie, 1998; pers. comm.). Dialine copies were made of the transparencies by the Rhodes University Cartography Unit. These dialine copies could be used for the digitizing process if so desired.

Having captured a sample of the international boundary and the main roads from the 1:250 000 topographic map, the covers were overlayed with the corresponding covers available on the South African 1:500 000 Topographic data set (ComputaMaps, 1997). From the slight discrepancy between the lines, it became clear that the 1:50 000 map series might be needed if greater accuracy was to be attained.

The Department of Geography at this stage had an incomplete set of 1:50 000 maps for Swaziland all dating from various years. It was necessary to order the latest map series covering the entire country. The most up to date 1:50 000 map series for the country were acquired from Map Office in Johannesburg.

The series consisted of thirty one maps which were printed in 1991. It is important to note that these maps were six years out of date. Some of the data features such as roads have changed since their production. The double lane highway between Mbabane and Manzini completed in July 1998, for example, will not be evident on the road cover of the atlas.

3.4 Step Three - Building the database

This stage has been described as "the most critical and often the most time-consuming part of the project", the reason being that the "completeness and accuracy of the database determines the quality of the analysis and the final products" (ESRI,1993:3-3). At the start of the project a journal was kept to keep track of the sequence of procedures that were completed and problems that were encountered. The rest of this chapter examines the building of the population and environmental atlas of Swaziland in detail.

The first step to building the database was to automate the data by converting the selected features on the paper maps, into a digital format recognisable by the computer, through digitizing. Digitizing is a process which can best be described as the tracing of map components classified into arcs (line features), polygons (area features), and points (buildings, trig points etc).

3.4.1 Capturing the first data layer (1:250 000 source map)

It was decided that the first data layer should be simple to digitize. This provided an opportunity to produce a sample cover relatively quickly, enabling familiarity with the range of processes involved as well as an assessment of the end product before embarking on the full automation of the atlas.

The first step in data capture involves assigning the map at least four tic registration points (ids). For each base map used in the atlas of Swaziland, six tic points were assigned, as "using more than four tics increases accuracy" (ESRI,1993:4-17). The tic points were written on the maps in pencil to ensure their order was not forgotten. The first data layer chosen for capture was the international boundary. The 1:250 000 topographic map of Swaziland was chosen as the base map for this first data layer as it provided the clearest outline out of all the 1:250 000 maps available at this stage.

The map was taped onto the digitizing tablet, ensuring as little wrinkling on the map surface as possible. It is important to ensure that the map is taped into a position where it has direct contact over the entire surface of the digitizing tablet so that errors which could result from the map slipping or creasing, are kept to a minimum.

Once the map had been taped smoothly onto the digitizing tablet, the ARC Digitizing System (ADS) was opened. The six tic ids were entered creating a blank cover with six tic points. Following the boundary line on the base map and pressing buttons on the keypad, the line was recorded as a series of x, y coordinate locations in digitizer units (inches). The resulting cover is shown in **Figure 3.1**.

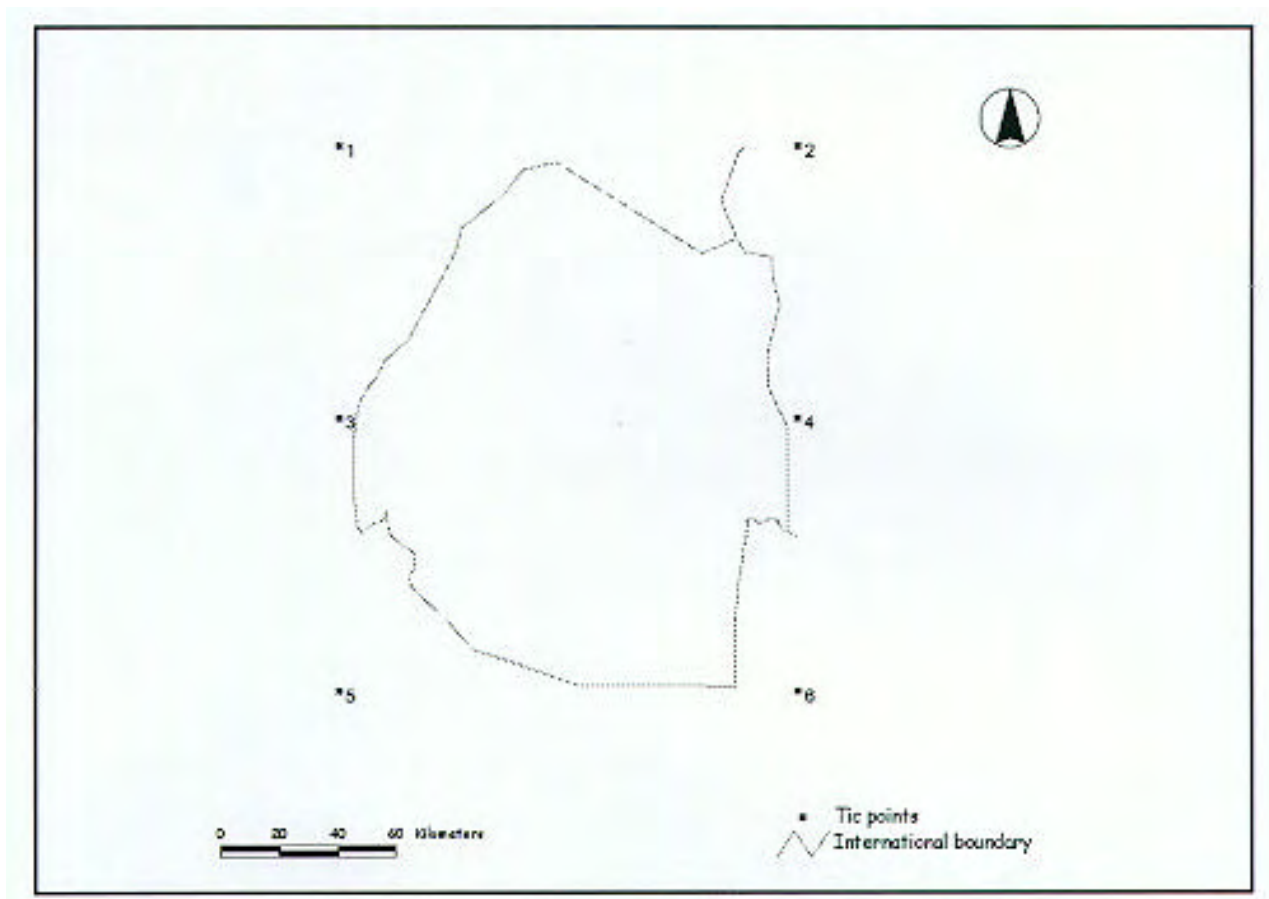


Figure 3.1: Swaziland's international boundary; the first data layer captured

3.4.2 Making the data usable

For various reasons, it is impossible to digitize without error. To make the new cover usable, "requires correcting the coordinate data to make it free of errors and topologically correct" (ESRI,1993:5-2). The topology of a cover describes the relationships between geographic features that have been digitized. Creating a topology manually for example, would involve recording some of the following; the direction in which the arcs were digitized, area size of polygons, the number of arcs that make up a polygon and their ids. PC ARC/INFO has two commands BUILD and CLEAN which carry out this process automatically.

Once the topology has been created, ARCEDIT is used for its "sophisticated capabilities for feature, attribute and graphics editing" (ESRI,1993:4-9). The program can be prompted to display and correct errors such as nodes which have not snapped to other nodes, polygons which have not been labelled and incorrect arc identification numbers that have been assigned. The international boundary was not a complex cover and few errors were indicated. Once a couple of the arcs had been joined by snapping their nodes together, the editing was complete. This editing alters the topology and it is necessary to reconstruct it by using the BUILD command again.

Whilst the base map was taped onto the digitizing table, the tar roads were digitized as an additional sample cover. The boundary coverage was opened in the ADS program. To do this, the program prompts the operator to enter the same six tic points that it recognises in the boundary cover. The tics were entered by placing the cross hairs of the keypad directly over the tic points on the map that were created for the boundary cover. The program then gave a root mean square (RMS) or tic registration error and asked if it was acceptable. The RMS error value "represents the amount of error between the original and new coordinate locations" (ESRI,1993:Glossary-37). The larger the figure, the greater the error. ESRI usually sets the error limit below 0.004 inches. Due to the susceptibility of paper maps to stretching and warping, it is suggested that an RMS error as high as 0.005 or 0.006 may have to be accepted. All of the covers created for the atlas were kept under an RMS error of 0.003.

At this stage, the captured data could be described as a simple line drawing and in this form the map as

a geographical tool is of little use to anyone. It does not have a physical location (latitude and longitude) in the real world. One would be unable to overlay this outline of Swaziland on a cover of South African rivers from the South African 1:500 000 Topographic data set (ComputaMaps,1997) for example. This would only be possible if the tic points assigned to the Swaziland cover had coordinates in latitude and longitude.

Assigning latitude and longitudinal coordinates to the six tic points involves **transformation** of the cover. This converts the various features that have been captured in digitizer units, to their corresponding real-world locations (ESRI,1993). Transforming the cover requires the creation of a master tic file which holds the x and y tic values of all the base maps used. The x-tic and y-tic values were recorded in decimal degrees.

Each tic point marked on the base map has a reading in latitude and longitude. Each coordinate is recorded and converted to decimal degrees (see **Table 3.1**). The following equation is used to calculate the coordinates in decimal degrees:

Decimal degrees = Degrees + Minutes/60 (ESRI 1993:7-15)

One minute = 0.01666667 of a degree (60 minutes in one degree, $1/60 = 0.01666667$)

Tic id 1 on the boundary cover for example lies at 31 45' on the x axis and 25 40' on the y axis.

$45 \times 0.01666667 = .749997$

$40 \times 0.01666667 = .666664$

In decimal degrees, $30\ 45' = 30.749997$ and $25\ 40' = 25.666664$

Tic ID	XTIC (DU) YTIC (DU)		XTIC (DM) YTIC (DM)		XTIC (DD) YTIC (DD)	
1	26.3200	39.4920	30 45'	25 40'	30.749997	- 25.666664
2	48.7760	39.5660	32 10'	25 40'	32.166666	- 25.666664
3	26.4990	24.9740	30 45'	26 30'	30.749997	- 26.499998
4	48.7530	25.0660	32 10'	26 30'	32.166666	- 26.499998
5	26.6420	10.4750	30 45'	27 20'	30.749997	- 27.333332
6	48.7520	10.5620	32 10'	27 20'	32.166666	- 27.333332

Table 3.1: The first six tic ids shown in Digitizer Units (DU) as they are digitized, Degrees and Minutes (DM) as read off the map and Degrees Decimal (DD) after transformation.

Once a tic file of real world coordinates has been created, the cover in digitizer units can be given a location in the real world using the command TRANSFORM. In this example, the main roads were digitized on to the boundary cover, the cover was edited and the topology recreated using BUILD. The cover was then transformed using the following steps.

create troad swazitic (A cover called troad is created. It will hold the tics in real world coordinates which have been copied from the master tic file SWAZITIC)

transform road troad (each tic in digitizer units (road) is transformed into its location in decimal degrees; the original cover road stays in digitizer units)

build troad line (recreates the line topology)

To see how the resulting roads cover compared with a commercially available data set, it was overlaid with the South African 1:500 000 Topographic roads cover (ComputaMaps, 1997). To the naked eye, there did not appear to be a significant discrepancy in the digitizing of the road lines. Using the measuring tool the difference between the roads at one specific section chosen at random, was calculated at 610 meters. Digitizing the boundary from larger scale maps held the possibility of attaining a more accurate result as well as being able to include greater detail. On the 1:50 000 maps, the main roads as well as secondary and 'other' roads could be captured. Waiting for the ordered 1:50 000 map series to arrive from Johannesburg, the international boundary was digitized off the 1:50 000 maps available in the department.

3.5 Digitizing the international boundary (1:50 000 maps)

Twenty out of thirty two 1:50 000 maps depict the international border of Swaziland. Six tic points were assigned to each map. It was realised that in order to transform these covers, a new master tic file incorporating the extra tic ids would have to be created. This tic file had 78 tic points which accounted for all the tic points of the twenty sheets (see **Figure 3.2**)

To produce a single coverage of a feature after digitizing off 31 maps, the maps ultimately have to be joined. It becomes particularly important to keep a note of the order of the tic ids when dealing with covers that have been captured from a series of adjoining maps. Two covers that need to be joined will have to share at least two of the same tic ids.

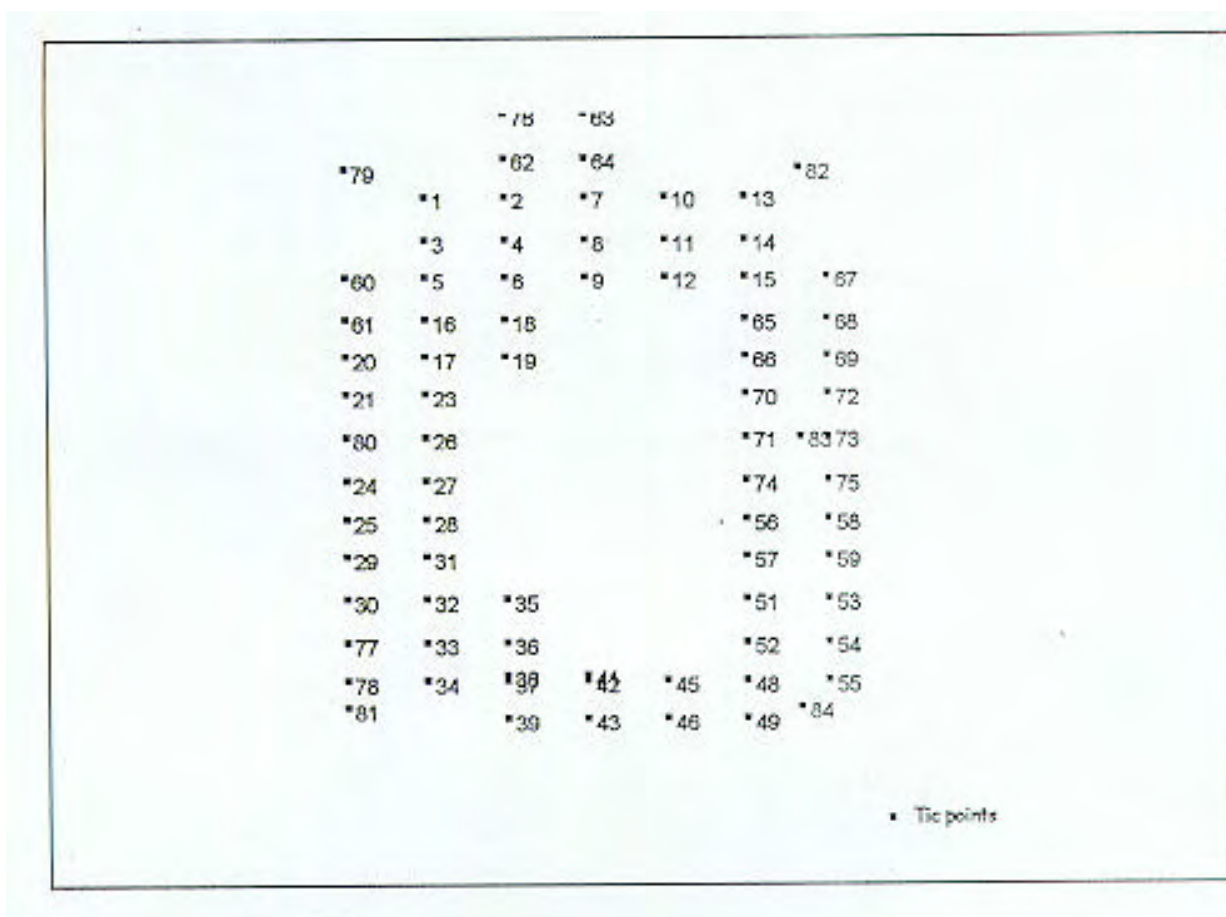


Figure 3.2: Location of the 78 tic points in the master tic file

Having digitized all the boundary lines from each map, they needed to be transformed into real world coordinates so the adjacent covers could be EDGEMATCHed and MAPJOINed. EDGEMATCH "is used to match border coordinates between coverages that will later be joined" (ESRI,1993:7-30) and MAPJOIN "creates a new coverage containing all the features and attributes from (all) input coverages" (ESRI,1993:7-45).

At this stage working knowledge was still sketchy and the use of the MAPJOIN command was not fully understood. The command GET was more familiar and was used instead. This involved opening one of the boundary covers in ARCEDIT, selecting the editfeature (arcs), and fetching each of the remaining 19 maps using GET. Editing was completed by snapping nodes together which didn't quite meet. The topology was recreated using BUILD. Overlaying the boundary with a cover from the South African 1:500 000 Topographic data set (ComputaMaps,1997) indicated that this cover achieved a closer representation to the commercial data set than the boundary captured from the 1:250 000 map had. Using the measuring tool, the difference between the boundaries was calculated at six meters on the ground compared to 400 meters on the ground for the boundary captured from the 1:250 000 map.

3.6 Digitizing the district boundaries (1:250 000)

Digitizing the district boundaries from the 1:250 000 topographical map of the country proved to be difficult. The boundary is indicated as a series of crosses, making their representation unclear. The boundaries appeared to be a lot clearer on the dialine copy of the population distribution map.

The difficulty of working with dialine copies became apparent when the first attempt at digitizing the district boundaries was made. Digitizing the Shiselweni district boundary, the line disappeared as it met the Ngwavuma river. Looking along the boundary line, it became clear that the draughtsman had simply stopped recording the boundary as soon as it met the Ngwavuma, Mhlatuze, Mkhondvo and Tsawela rivers. The boundary is in fact defined by these features, and although logical in hindsight, it was confusing at the time and destroyed the flow of digitizing. It became apparent that the population density and population distribution dialine copies were not suitable as data sources for the atlas. It was decided that the district boundaries would be digitized from the 1:250 000 topographic map of Swaziland whilst waiting for the 1:50 000 map series to arrive.

Having completed the digitizing of the district boundaries from the 1:250 000 map, the cover was edited. It was then transformed using the master tic file which had been created for the international boundary covers. Opening the transformed cover in ARCEDIT, a problem was immediately apparent. The districts lay in the top left hand corner of the screen whilst the international boundary filled the centre of the display (see **Figure 3.3**).

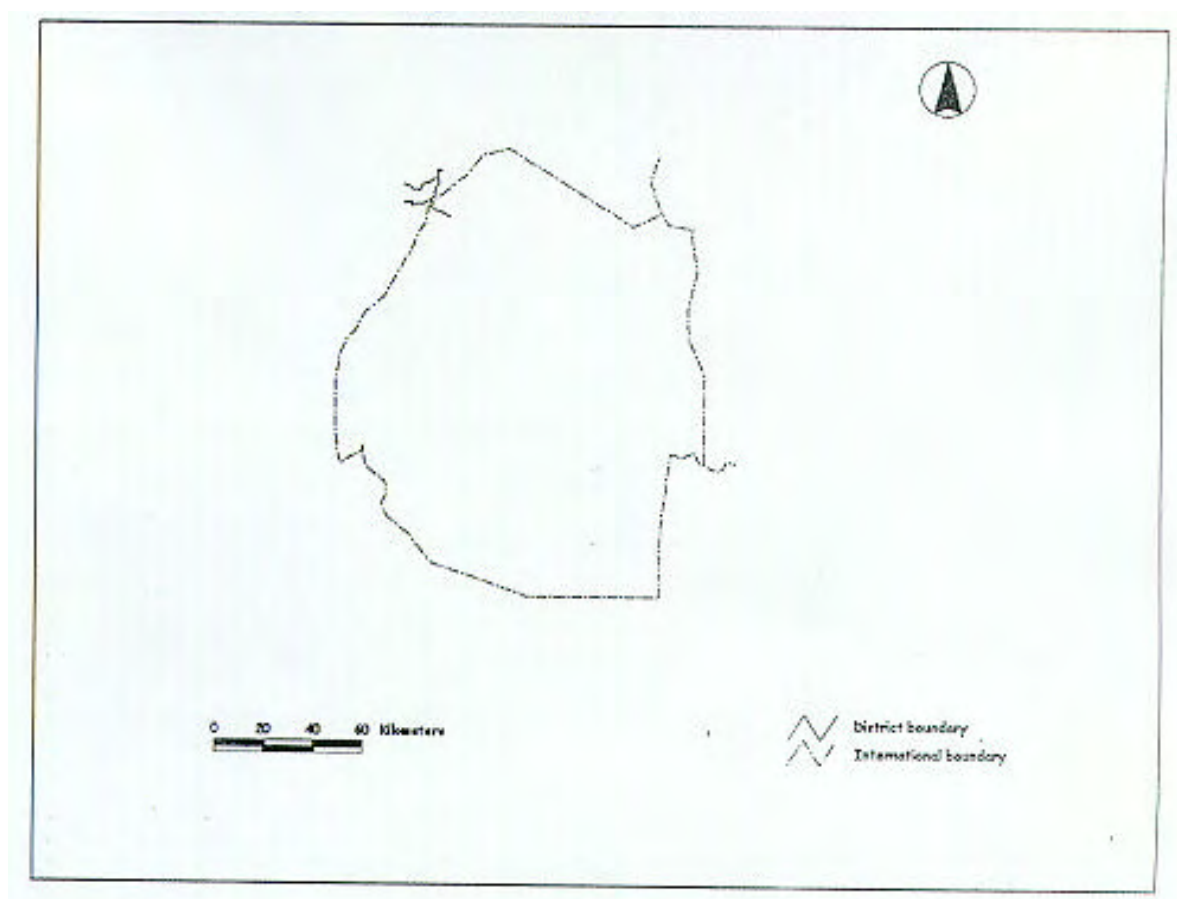


Figure 3.3: The districts lie in the top left hand corner due to incorrect allocation of tic ids.

By retracing the steps taken up to the transformation of the cover, the problem became apparent. The district cover had six tic ids 1,2,3,4,5 and 6 assigned to it. When the cover was transformed into the master tic file, it fell into the corresponding tic ids of that file. Evident in **Figure 3.2** is that the tic ids

1,2,3,4,5 and 6 sit in the top left hand corner. The tic file for the district boundary had to be opened and updated with the new ids shown below.

Previous tic id	Updated tic id	Previous tic ids	Updated tic id
1	1	4	73
2	13	5	78
3	22	6	55

The districts now appeared in the correct area within the international boundary but were not extending to its edges (see **Figure 3.4**). A distance of 7.74 kilometers was measured between the endpoint of the Hhohho/Lubombo district boundary and the international boundary.

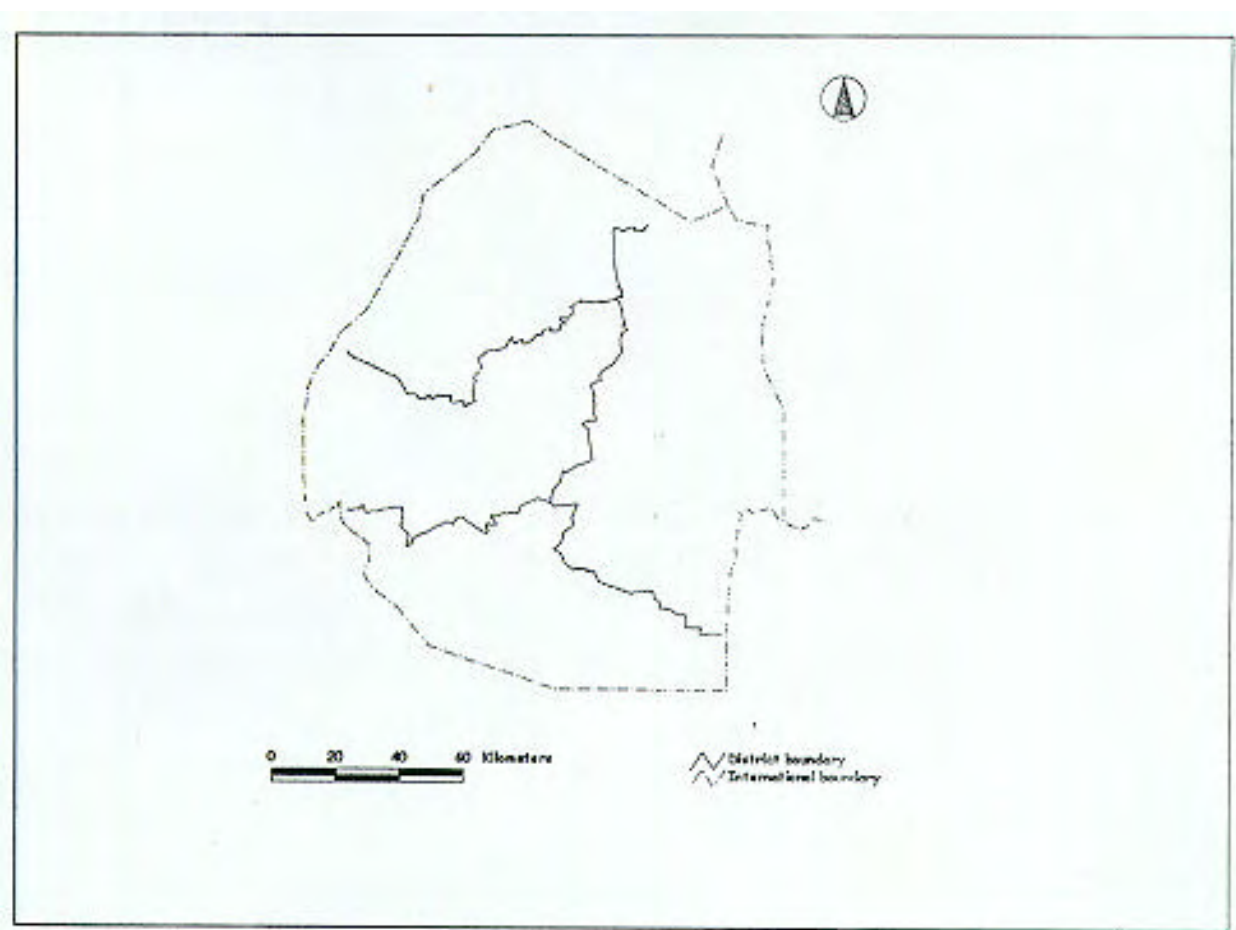


Figure 3.4: After correction of the tic points, the district boundary falls within the country but fails to extend to the international boundary (source:1:250 000 topographic map of Swaziland)

There were two possible explanations for this result; the source map (1:250 000 topographical map) may itself have been inaccurate in comparison to the boundary captured from the 1:50 000 map series, or there was a problem in the method being used. That the degree of error could imply a poor standard of map work in the topographic map of Swaziland, was worrying. This map has been used and is being used as the basis for several digital mapping projects for the country. The Department of Land Use and Planning in the Ministry of Agriculture has produced a series of land use maps in conjunction with FAO, using the 1:250 000 topographical map as the base map (Van Waveren, 1998:pers.comm.). The digital mapping project set up in July 1998 is also utilising this map. It was hoped therefore that the problem lay in the method and not in the inaccuracy of the base map.

Looking at the tic files, a slight discrepancy was found. Tic id 1 in the master tic file for example had recorded coordinates of -31 00' (y) and 25 45' (x). As expected, these were the same coordinates recorded for tic id 1 on the international boundary coverage. On the district boundary cover however, tic id 1 had a ytic reading of -30 45'. New tics ids (79, 80, 81, 82, 83, 84) were given to the district cover and added to the master tic file, with their correct coordinates in degrees decimal. The covers were opened in ARCEDIT. The districts merely seemed to have shifted northwards, with the degree of mismatch still considerable (see **Figure 3.5**).

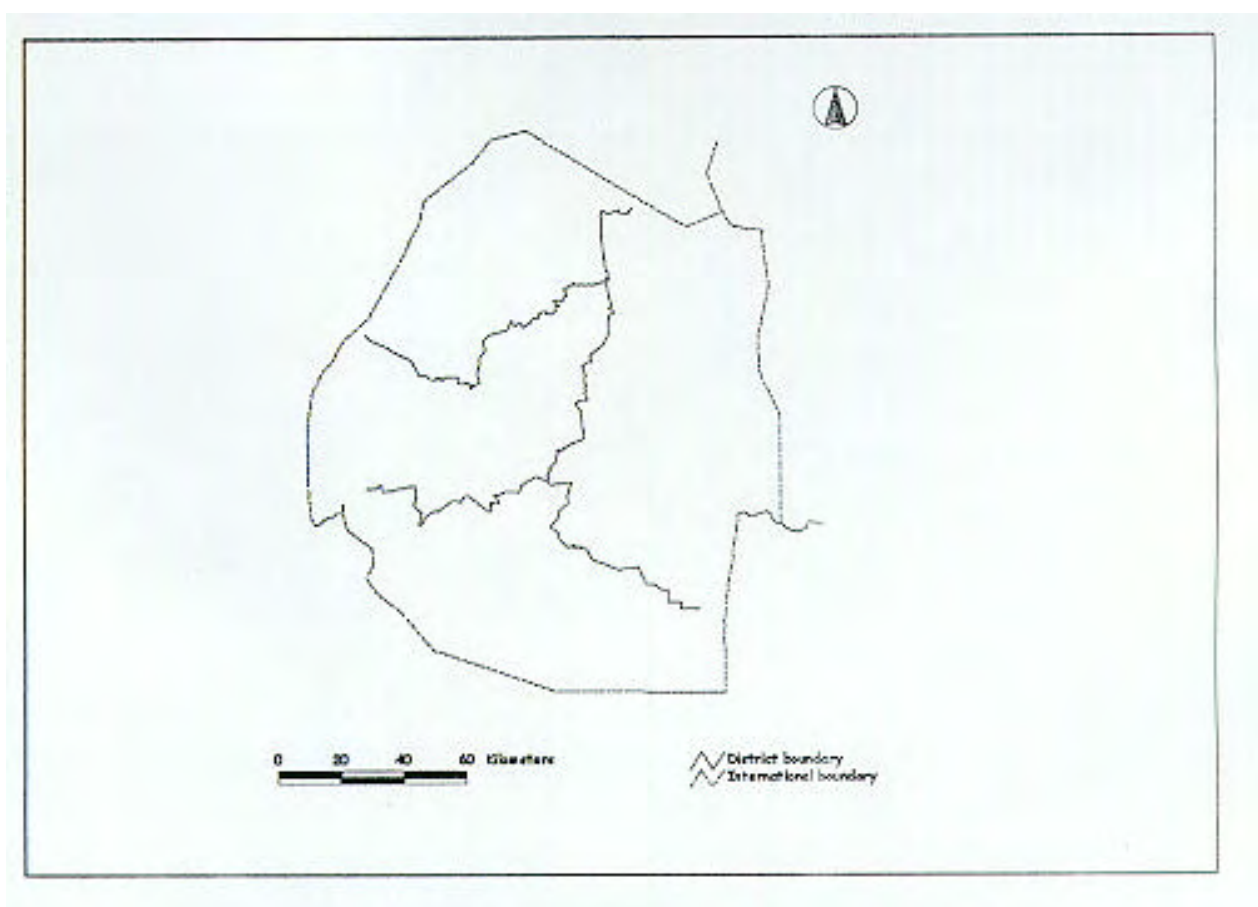


Figure 3.5: The districts merely shift northwards after tic ids have been altered

A second option was considered and that was to use a command which would calculate the distance of the districts from the boundary and extend the lines, clipping the two covers together. Inexperience resulted in the use of the command UNION. This command requires two polygonal spatial data sets; the international boundary was a polygon cover, but the districts were an arc cover. There was no way that this would have worked. Having used UNION, the result was viewed in ARCEDIT. A problem was immediately apparent, when the district boundaries appeared in the top half of the screen with the international boundary in the bottom half, evident in **Figure 3.6** below. This was caused by trying to join a transformed international boundary cover with an untransformed district boundary.

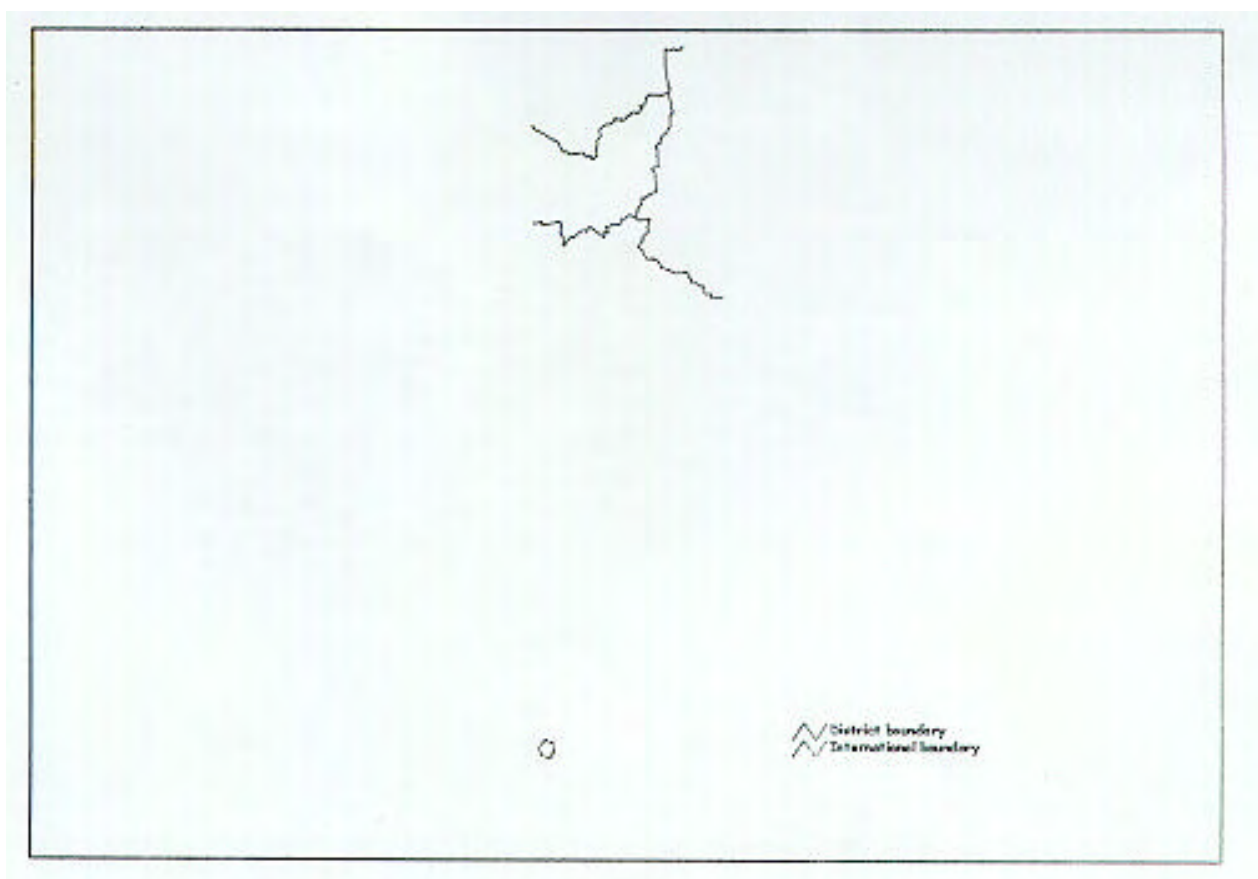


Figure 3.6: The result of attempting to UNION a transformed international boundary with an untransformed district boundary cover

At this stage, the 32 1:50 000 map sheets had arrived from Johannesburg, and it was decided that instead of spending any more time on the districts from the 1:250 000 map, it made more sense to digitize straight from the 1:50 000 map series.

3.7 Capturing Data Layers

3.7.1 Digitizing the districts (1:50 000 map series)

Before digitizing the district boundary entirely, a sample was carried out. A small section of the boundary between the Hhohho and Lubombo districts was digitized from two adjacent maps. The two samples were transformed, joined and opened in ARCEDIT. Immediately a problem was apparent. Sample one lay to the right of sample two; they were the wrong way round. Thus far the tic file had held the answer to problems experienced. The tic files for the two samples were opened (see **Table 3.2**).

\$RECNO	IDTIC	XTIC	YTIC
1	10	29.1100	34.4670
2	13		
3	11	29.2220	22.8320
4	14		
5	12	29.3310	12.6700
6	15		

\$RECNO	IDTIC	XTIC	YTIC
1	7		
2	10	47.561	34.388
3	8		
4	11	47.45	22.755
5	9		
6	12	47.335	12.604

Table3.2: Tic file of sample one (DU)**Tic file of sample two (DU)**

There was a discrepancy between the shared tic points 10, 11 and 12. In sample 2, both columns of YTIC values are fairly similar for the two covers, but the XTIC values are significantly different from each other. Ultimately, the covers were re-digitized. The covers were transformed and opened in ARCEDIT, appearing in the correct positions.

Problems that were experienced with the editing of these sample covers were as a result of inexperience with the software. Difficulty with the editing of the features such as selecting nodes and arcs were experienced. It had not been realised that it was not possible to edit a transformed coverage if any degree of accuracy was to be maintained. Editing should to be carried out whilst the covers are still in digitizer units. This was a basic mistake, but one which took time to sort out.

Once the covers had been edited, transformed and joined, the result showed a significant improvement compared with the districts that were digitized from the 1:250 000 map (see **Figure 3.7**). A measurement of 230 meters was taken from the endpoint of the Hhohho/Lubombo district boundary to the international boundary, compared to the measurement of 7.74 kilometers taken previously (**Figure 3.4**).

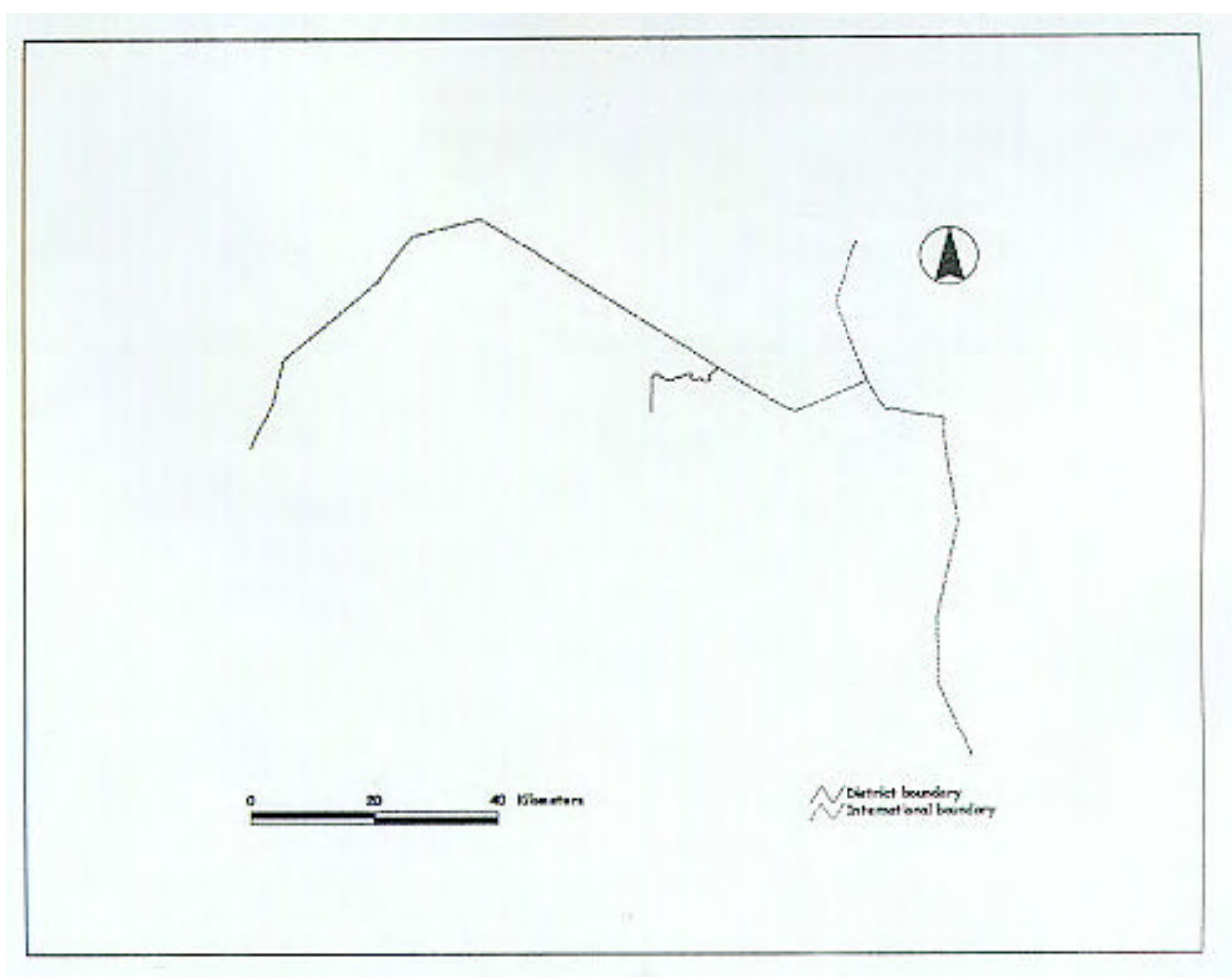


Figure 3.7: Sample of the Hhohho/Lubombo district boundary digitized from the 1:50 000 map series

Satisfied with the results of the sample, the district boundaries coverage was captured. Having been transformed, the coverage was built as a polygon and an arc coverage. It was opened in ArcView 3.0 as a polygon cover. In ArcView, the attribute table was opened and the district names added. This allows the user to open the districts and autolabel them if so desired. The final district coverage can be seen in **Figure 3.8** along with the international boundary for the country. The international boundary has a hotlink attached to it allowing the user to view a photograph of King Mswati III, the King of Swaziland.

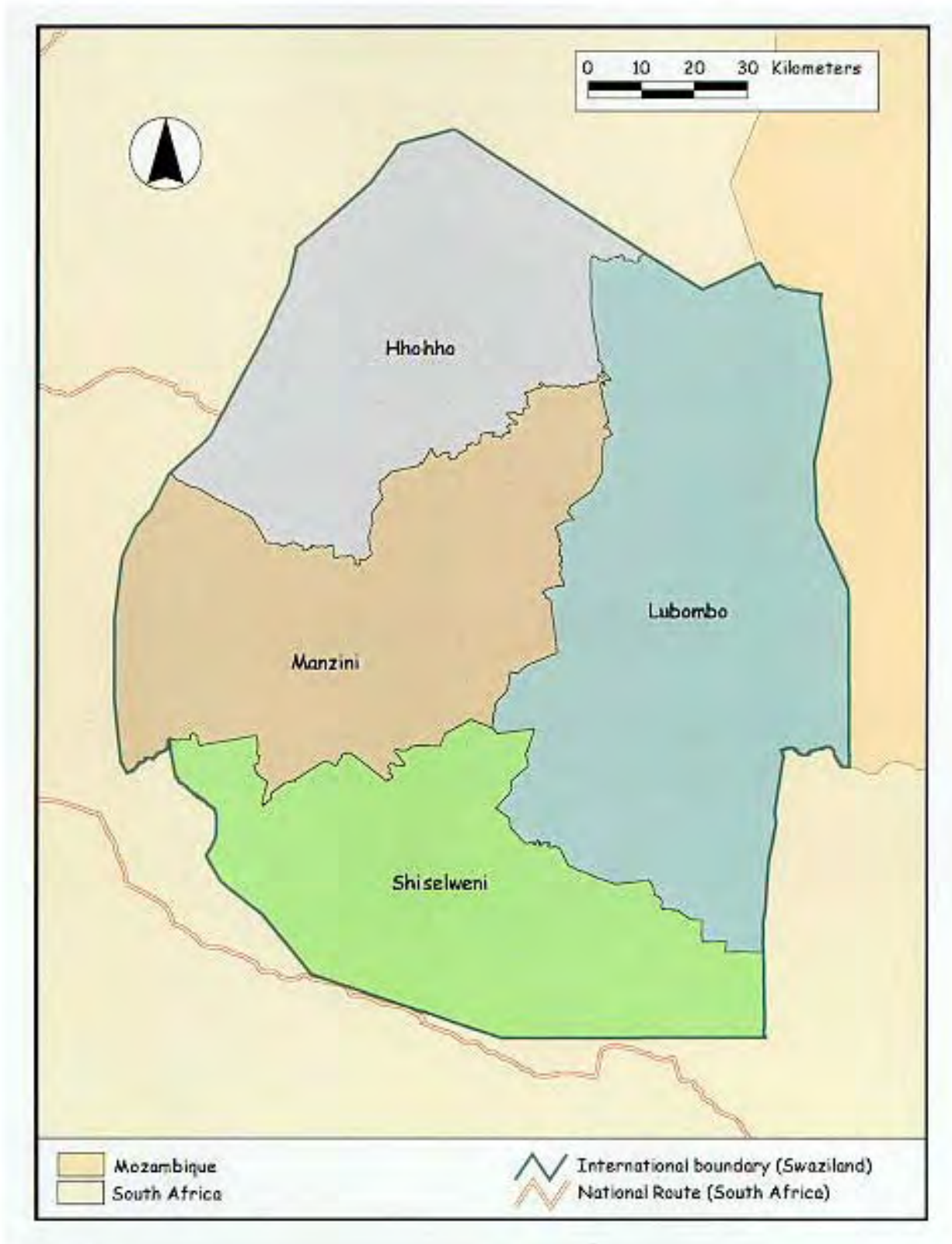


Figure 3.8: The international and district boundaries of Swaziland (1991)

The enumeration areas were chosen as the next data layer to capture since they would make up a significant part of the atlas. The base map was a 1:250 000 dialine copy and as such, several problems were anticipated.

3.7.1 Digitizing the enumeration areas (1:250 000 dialine copy)

A sample area was digitized, transformed and viewed. The enumeration areas appeared to be stretched sideways and were situated far from where they should have been (see **Figure 3.9**). The tic file was the first place to look for a problem. Looking at the sketch map which had been made of the tic points, it became apparent that the tics had been recorded incorrectly (see **Table 3.3**).

78	82		79	82
80	81	Instead of	80	83
79	83		81	84

Table 3.3: Tic file of enumeration areas sample

Once the tic ids had been corrected, the sample was re-digitized, edited and transformed with no problems immediately apparent (see **Figure 3.9**) The enumeration areas could now be captured.

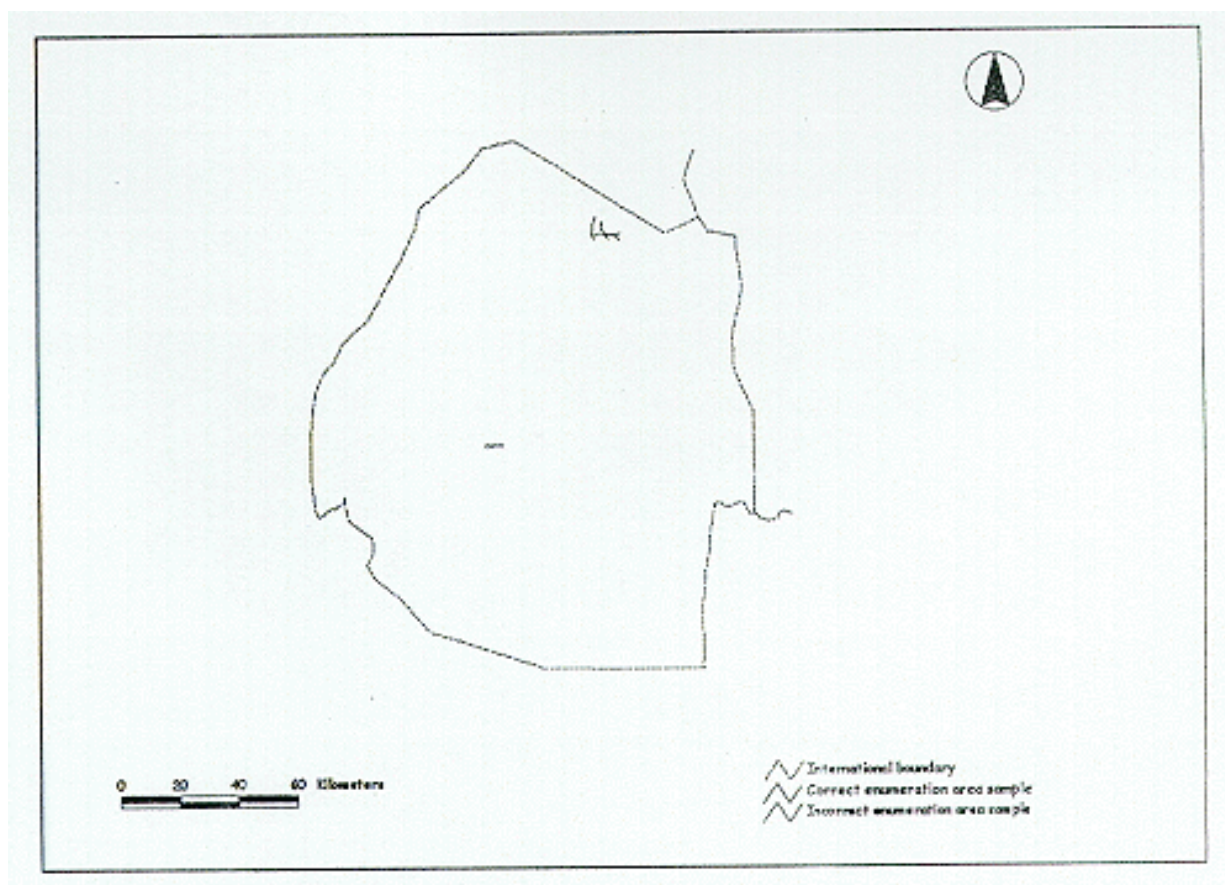


Figure 3.9: Enumeration area sample cover

The enumeration areas were digitized by district and saved in different covers. Apart from the fatigue of digitizing so many small lines, and keeping track of the areas which had been digitized, there were not too many problems capturing the enumeration areas. The first problem to become apparent, was related to the manner in which the base map had been drawn. As the enumeration areas were being digitized for Hhohho district, one of the parcels appeared to be a little more irregular in shape than the surrounding ones. Looking at the map, it didn't have an enumeration id number either. It was realised that the draughtsman had in fact drawn Mjoli dam in with the enumeration areas. This was only recognised when a break from digitizing was taken. It is the only body of water which has been included in the map. Some of the lines on the dialine copy are very faint and further mistakes resulted from missing out boundary lines. These mistakes were only noticed later when the cover was opened in ArcView 3.0.

Once the enumeration areas for each district had been digitized, the covers were cleaned to a fuzzy tolerance of 0.0000001 and built for polygons. The fuzzy tolerance "defines the coordinate resolution of

all arcs" (ESRI,1993:Glossary-14). It is measured in coverage units and is carried out during the CLEAN process. If the fuzzy tolerance is too large, the arc coordinates (vertices) will be snapped together. The visual effect of this on a cover with many curved lines would be a series of noticeably jagged lines (see **Figure 3.10**).

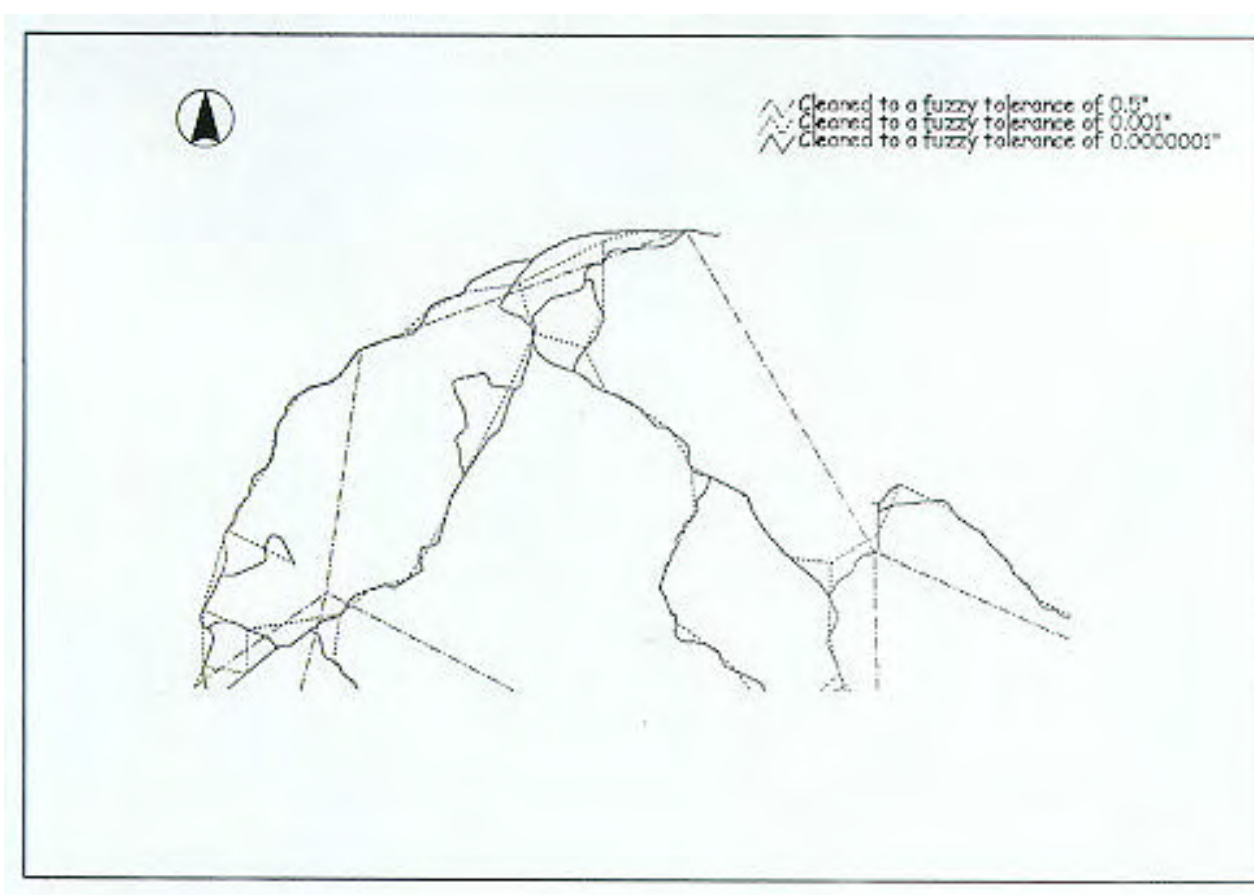


Figure 3.10: An example of the effect of different fuzzy tolerances on a coverage after CLEAN has been carried out (section of Hhohho enumeration areas)

Below is an example of the steps that were carried out for each district:

describe ennuma (description of the covers' status e.g. there are 716 arcs, 1032 nodes, 12 polygons and 672 edit masks before cleaning)

tolerance fuzzy = 0.0000001 (to change the fuzzy tolerance from the 0.0000002 default value)

clean ennuma

build ennuma

arccedit (to edit the enumeration coverage)

copycov ennuma ennumac (once edits have been made, a copy is made incase the cleaning process creates further problems with the cover)

clean ennumac (recreate topology as editing has been carried out on the cover)

describe ennumac (The covers' status is now 716 arcs, 523 nodes, 197 polygons after editing and cleaning)

build ennumac

build ennumac line

ENNUMAC = enumeration areas for Shiselweni region digitized, edited, cleaned and built.

The enumeration parcel arcs were assigned a different user id for each district. This allowed the enumeration areas from the different regions to be drawn in a different colour when opened in ArcView 3.0 if required.

Small problems became apparent during the editing process. In one of the enumeration district covers there were a couple of arcs which had different values from the rest. This was a minor error which can occur easily during digitizing where the user id for an arc is set incorrectly. In another example, there were 15 arcs with ids as long as 9 units e.g. 259591508. In this case, the user increment can't have been set at zero. Each time a point was entered on the keypad, the id value increased by the number that was set as the user increment. To correct this, all arcs with an id greater than 1 were selected and the correct user id was assigned.

Having made the necessary corrections, the covers were joined and opened in ARCEDIT. The international boundary cover was overlaid and immediately a problem was evident. The boundary did not fit; the enumeration areas appeared to have 'slipped' southwards. Looking at the coordinate values for the tic points 81 and 84 in the main tic file, it was realised that they were incorrect. Tic points 81 and 84 should have had a line of latitude of 27 27' instead of 27 20'. It was thought that extra seven minutes may have made all the difference. Having corrected the main tic file, all of the covers that had been created up to this point were transformed again. The enumeration areas were opened and overlaid with the international boundary. Despite the correction of the coordinates for tic points 81 and 84, the enumeration areas still hung outside the international boundary on the southern border of the country. There appeared to be little else that could be done except to assume that the source map was inaccurate. The command CLIP was used as a "cookie cutter" (ESRI,1993:Glossary-5), to delete the overhanging arcs. CLIP ensures the "spatial extraction of those features from one coverage that reside entirely within

a boundary...in another coverage" (ESRI,1993:Glossary-5). This operation appeared to be successful.

Whilst using BUILD, the computer bailed out with the message: "An intersection was detected while building polygons. Intersection coordinate = 31.40955 -25.77056 use CLEAN instead of BUILD or alter fuzzy tolerance if using CLEAN." Unsure what an intersection was, the area was located using the coordinates given in the computers prompt message. The intersection turned out to be a small dangling arc which the program identified as a possible error (see **Figure 3.11**). CLEAN "corrects undershoots and overshoots within a specified tolerance" (ESRI,1993:5-10) whereas BUILD "assumes that the coordinate data is correct" (ESRI,1993:5-10). The tolerance in this case would have been such that the arc would have been deleted unless the tolerance was altered. Realising that the arc was an error, the fuzzy tolerance was not altered and the command CLEAN was used followed by BUILD.

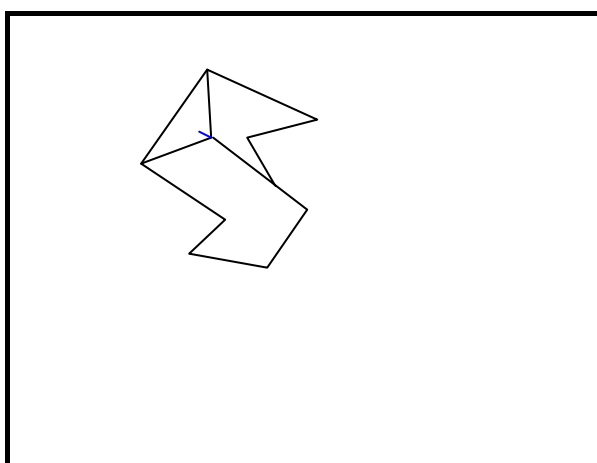


Figure 3.11: An example of an intersection The intersection identified by the program is a small line shown on the diagram in blue.

The enumeration area covers were opened in ARCEDIT. At this point, the first problems with hardware were experienced. The computer bailed out of ARCEDIT after trying to save the complete enumeration coverage. Subsequently ARCEDIT could not be opened, and the message "could not unpack program (Disk full?)" appeared. Trying to find the problem, T\$ARC (error files) were sought and deleted. This did not help and it became clear that a significant amount of space would have to be freed up on the hard drive. Having cleared some space on the hard drive the enumeration cover was built for arcs, and polygons.

3.7.2.1 Opening the cover in ArcView 3.0

The cover was opened successfully in ArcView 3.0. Looking at the attribute table, however, there were some polygons with a label of 0. By selecting these polygons in the table, they were highlighted in yellow on the map. Some were very difficult to see, and only by selecting the tool to 'zoom to selected feature', were they identifiable. They were sliver polygons defined as "small areal features commonly occurring along the borders of polygons following the overlay of two or more coverages" (ESRI, Glossary-41). The other polygons with a label of zero were polygons whose nodes had not snapped together so they were not entirely closed. This was a simple mistake caused by the fact that the original cover had not been edited before CLIP was used; the clip coverage had been edited instead. The original cover was opened and the errors were corrected.

It was decided that by using the command EDGEMATCH thereby using links "to connect the locations in one coverage to the locations of the matching features in the adjacent coverage" (ESRI, 1993: Glossary-12) followed by MAPJOIN, fewer errors would arise in the resulting cover. Once the enumeration covers had been matched and joined to each other and the regional boundary, each of the polygons was labelled with a unique identifier. The resulting cover was then clipped to the international boundary. Opening the cover in ArcView 3.0, and looking at the attribute tables, some polygons still registered an id of zero. The sliver polygons were however no longer a problem.

Whilst the cover was open in ArcView 3.0 the same cover (a copy) was opened in ARCEDIT. Again, the polygons registering an id of zero were selected and highlighted. The polygons were checked in ARCEDIT and corrected. Once sure that the polygons had been closed, the same steps of edgematching, mapjoining and clipping were repeated. The new cover was opened in ArcView 3.0. This time all the polygons had labels. The process of inputting statistical data for each of the 965 enumeration areas into the attribute table began.

3.7.2.2 Entering data into the attribute tables

Data input was carried out directly into the attribute table of the coverage whilst it was open in ArcView 3.0. The next problem surfaced during this process. There did not appear to be a corresponding polygon for one of the enumeration parcel ids recorded in the statistical volume. The problem was caused by an arc which had not been captured. Returning to PC ARC/INFO, the missing arc was digitized. Having

altered the topology, the cover had to be built. During the BUILD process, the attribute table was updated thereby deleting all data input which had taken place up to this stage. Through experimentation, it was discovered that if the data was input into the coverage pat file in PC ARC/INFO, data was not deleted during the CLEAN and BUILD processes.

To ensure that each polygon had been captured, the following process was carried out. Each enumeration parcel identification number in the census volume (Census Department, 1986) was identified on the digitized map. Any missing polygons were identified and the errors were corrected. The final enumeration area coverage can be seen in **Figure 3.12**.

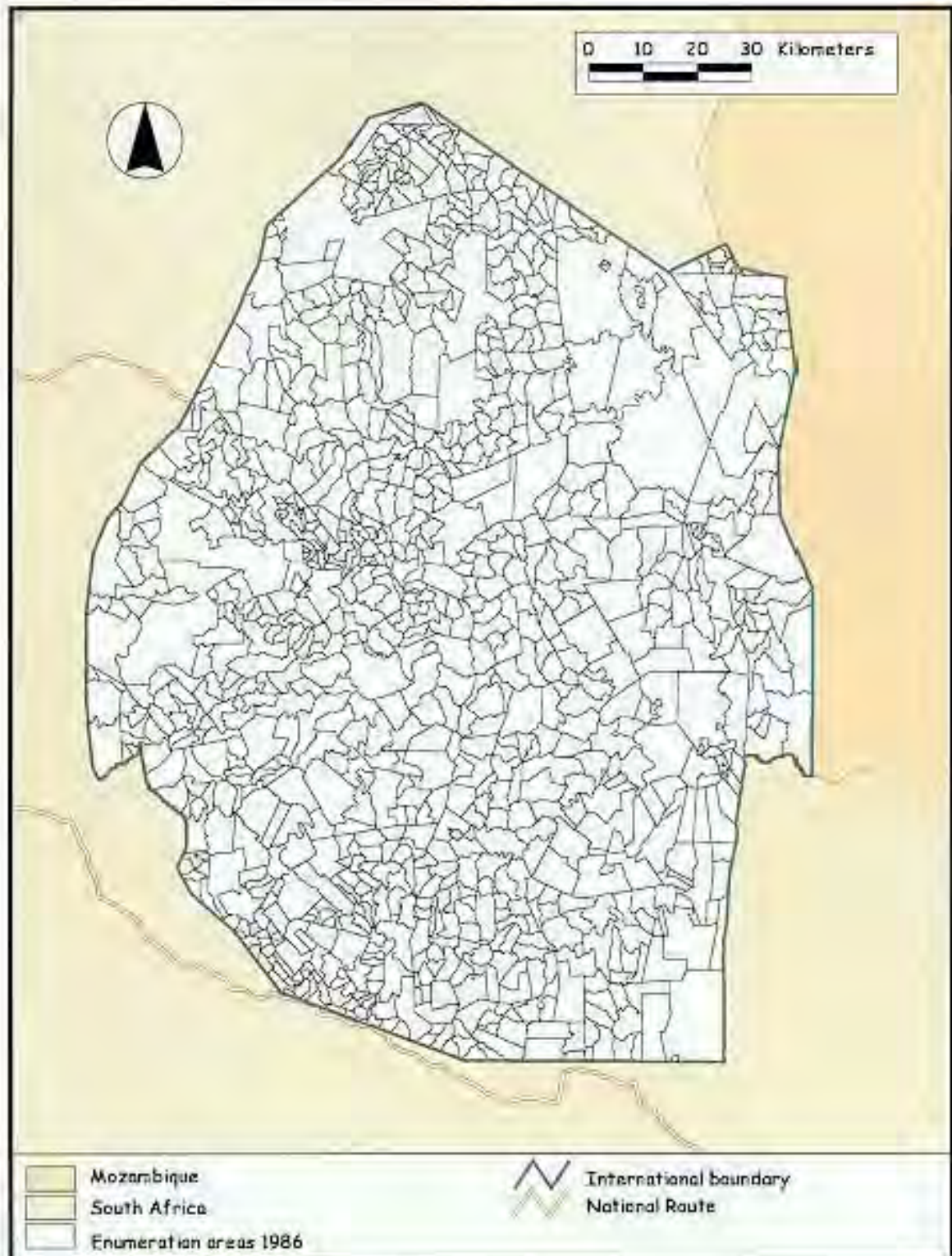


Figure 3.12: Enumeration Areas for Swaziland (1986)

The following data, for each of the 965 enumeration areas was fed into the attribute table of the Enumeration Areas cover.

Data fed into the attribute table of the Enumeration Area (1986) cover	Field name
enumeration area identification number	Ea_id
area (sq kms)	Area
population density	Density
number of homesteads	Tenure
number of households	Homesteads
land tenure	Households
Males 0-4 years	M_0to4
Males 5-9 years	M_5to9
Males 10-14 years	M_10to14
Males 15-19 years	M_15to19
Males 20-34 years	M_20to34
Males 35-49 years	M_35to49
Males 50-64 years	M_50to64
Males 65 plus	M_65plus
Females 0-4 years	F_0to4
Females 5-9 years	F_5to9
Females 10-14 years	F_10to14
Females 15-19 years	F_15to19
Females 20-34 years	F_20to34
Females 35-49 years	F_35to49
Females 50-64 years	F_50to64
Females 65 plus	F_65plus

Table 3.3: Data fed into the attribute table of the 1986 Enumeration Areas cover

As a trip to Swaziland was imminent, the table was exported in dBASEIV format so it could be worked on in Quattro Pro IV in the field and later linked back to the spatial cover.

With the spreadsheet opened in Quattro Pro IV, the enumeration registration ids field was sorted in ascending order. Having learnt from experience, it was decided that the enumeration registration ids in the statistical tables would be marked off against the ids in the attribute table as a final check. There were three enumeration areas (label ids 445, 446, and 447) which did not have an enumeration registration number allocated to them. **Figure 3.13** shows that the figure 44204/7 lies above the parcels, but it is unclear which id belongs to which parcel. Ultimately the polygons were labelled 44204 - 44207 starting from the left.

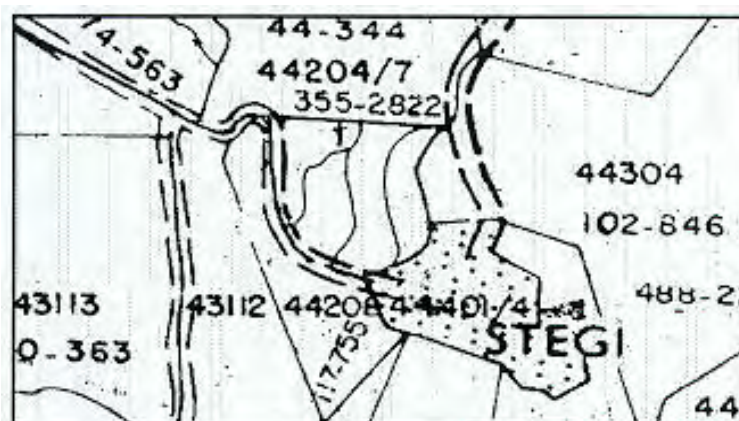


Figure 3.13 A section of the 1:250 000 enumeration areas (1986) map

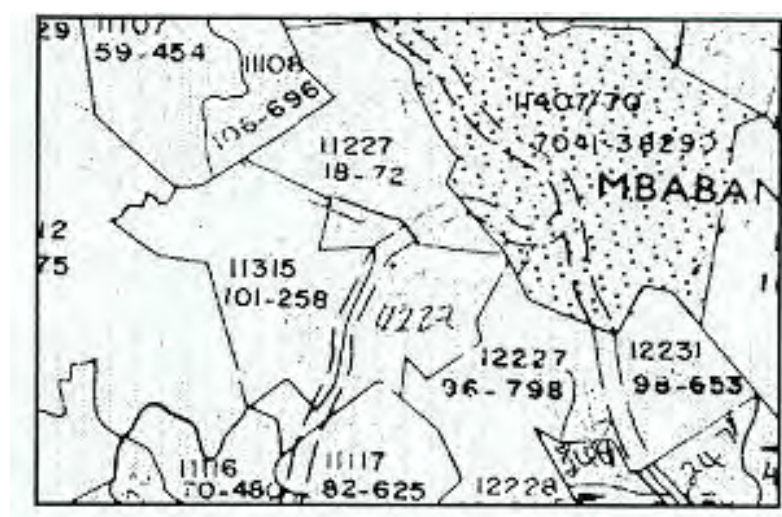
Several errors regarding the enumeration areas were discovered in the table and are outlined below.

Hhohho district

(a) Enumeration areas **11402 - 11406**. On the map, a small enumeration parcel for Piggs Peak town is outlined with the label 11401/6. The "/6" is almost obliterated by the enumeration boundary line. The label was read as 11401. It had not been realised that whilst one enumeration parcel was drawn, the parcel encompassed the six enumeration areas; 11401, 11402, 11403, up to 11407. The delimitations are not indicated within the parcel as there is no space.

(b) Enumeration areas **11408 - 11470**. This caused a problem similar to the one above. Outlining the capital city of Mbabane, indicated as one parcel on the map, there are in fact seventy parcels within it which are not indicated. The parcel is labelled as 11407/70.

c) Enumeration area **11227** had been recorded twice on the map in two separate enumeration parcels. One of the parcels had been labelled manually (see **Figure 3.14**). With two separate parcels, but only one identity number, it was not clear what should be done. Having obtained the provisional enumeration areas map for the 1998 Census, this enumeration parcel was recorded as a single area and this was used as a guide to make the area one complete parcel.



**Figure 3.14: A section of the 1:250 000 enumeration areas (1986) map
Manzini district**

- a) Enumeration area **12234** had been labelled 12834 on the cover captured. Through a process of elimination it was discovered didn't exist. It had be labelled incorrectly.
- b) Enumeration area **21201** again, had an id which had been incorrectly read; it was recorded 21209 instead of 21201
- c) Enumeration areas **21401 - 21402**. Reading the label as 21401/2, it was evident in this case that more than one parcel was being referred to. Error messages were prompted when the figure was recorded in the spreadsheet with a 'back slash'. The parcel was therefore recorded in the table with an id of 214012. I had not realised that when working in ArcView 3.0, that when choosing a 'New Field' to add to the table, the option 'string' should have been taken so that the id could have been recorded as 22401 - 22402.
- d) Enumeration areas **22401 - 22415** The parcel had not been omitted, but had been given an id of 2240115. The same was found to be true for nine other polygons.
- e) Enumeration area **22451** was actually missing; it needed digitizing and labelling.

Shiselweni district

- a) Enumeration area **31108** was labelled incorrectly as 31170
- b) Enumeration area **31124** was missing and needed to be digitized and assigned a label; two other parcels had been omitted in this district.

Lubombo district

Two polygons were found to be missing and needed to be digitized and assigned a label.

Looking for some of the enumeration identity numbers on the map was tedious. In some cases the numbers were difficult to make out, so to solve this the 1:175 000 provisional enumeration areas map for 1998 census that had been acquired was consulted. Some of the numbers were easier to make out on this map.

3.7.2.3 Correcting the final errors

Returning from Swaziland with a list of the errors which needed correcting, the cover was opened in ADS. The missing arcs were digitized, incorrect labels were corrected and arcs that had been added by mistake were deleted. It was clear that the dialine copy which had been used to digitize up to this point, was too creased and folded to digitize accurately from. The original sepia transparency of the enumeration areas was used instead.

To use the sepia transparency, the tic points had to be marked on the map in the exact location that they were on the dialine copy. To do this, the two maps were placed on a light table which made the points clearer to see. After numerous attempts at getting a lower value, an RMS error of 0.006 was accepted. Opening the cover, each of the six tic points were zoomed into. The cross hairs of the keypad were placed over the tic points on the map and zero was pressed on the keypad. This indicated where the digitizer tablet was reading the location of the tic point. Tics 79, 80 and 81 seemed to be fairly accurate, but tic points 82, 83 and 84 were clearly off target. This error could have been the result of inaccurate tracing of the tic points from the dialine copy to the sepia transparency. Another explanation could be that the dialine copy was so well used by this stage, that the paper may have stretched. Inaccuracy on the base map would have affected the accuracy of the tracing.

A minimum of four tic points were needed to be able to digitize the missing arcs which meant that the tic points 79, 80 and 81 could be used, plus one other. To choose the fourth tic point, the most accurate of the remaining tics (82,83 and 84) was located. Using the four tic points, an RMS error of 0.003 was achieved.

The missing arcs were digitized and the new polygons were labelled. The arc enclosing the parcel 854 was deleted; it had been digitized as a parcel boundary where upon closer inspection it turned out to be a road (see **Figure 3.15**). The topology of the edited cover was recreated using BUILD. Opened in ArcView 3.0 again, yet another error was found. One of the arcs that needed digitizing had been omitted. The mistake was frustrating, but there was no other option than to return to ADS and digitize it.

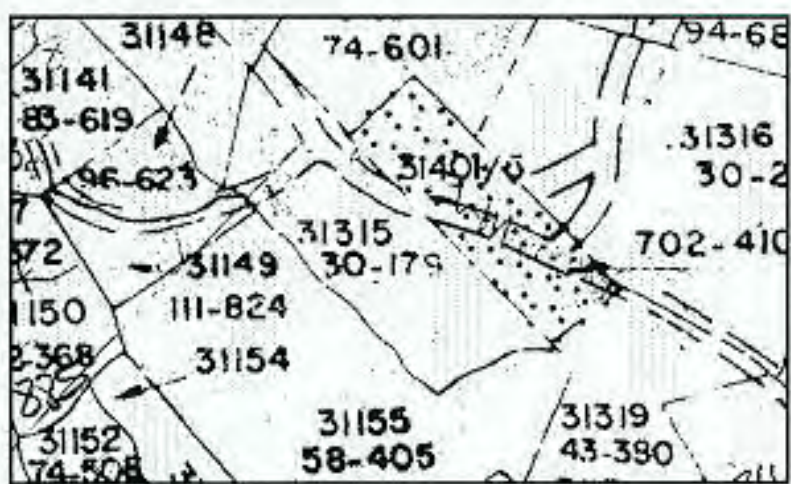


Figure 3.15: A section of the 1:250 000 enumeration areas (1986) map

The cover had been checked so many times at this point, that meeting with any more digitizing errors was unlikely. One last check however indicated that parcel number 610 was missing. The cover before the CLEAN process had been carried out was opened in ARCEDIT. On close inspection, it was clear that the parcel was there. One of two things could have occurred; the arc could have been deleted accidentally, or it could have been deleted during the CLEAN operation. In ARCEDIT it was discovered that the arc in question needed to be snapped to another node to enclose it. It is likely therefore that the arc was identified as an error and deleted during CLEAN. The topology was built one last time. The cover was opened again in ArcView 3.0 and checked thoroughly for any errors. The cover finally appeared to be error free, and the process of entering data from the statistical volumes was carried out.

Examples of maps produced using the data entered in to the attribute table of the enumeration area cover can be seen in **Figures 3.16 to 3.21**. **Figure 3.16** shows population density by enumeration area, **Figure 3.17** shows land tenure, **Figure 3.18** shows the number of homesteads and **Figure 3.19** shows the number of households per enumeration area. The distribution of females over the age of 65 is displayed in **Figure 3.20**, with **Figure 3.21** indicating the distribution of males over the age of 65.

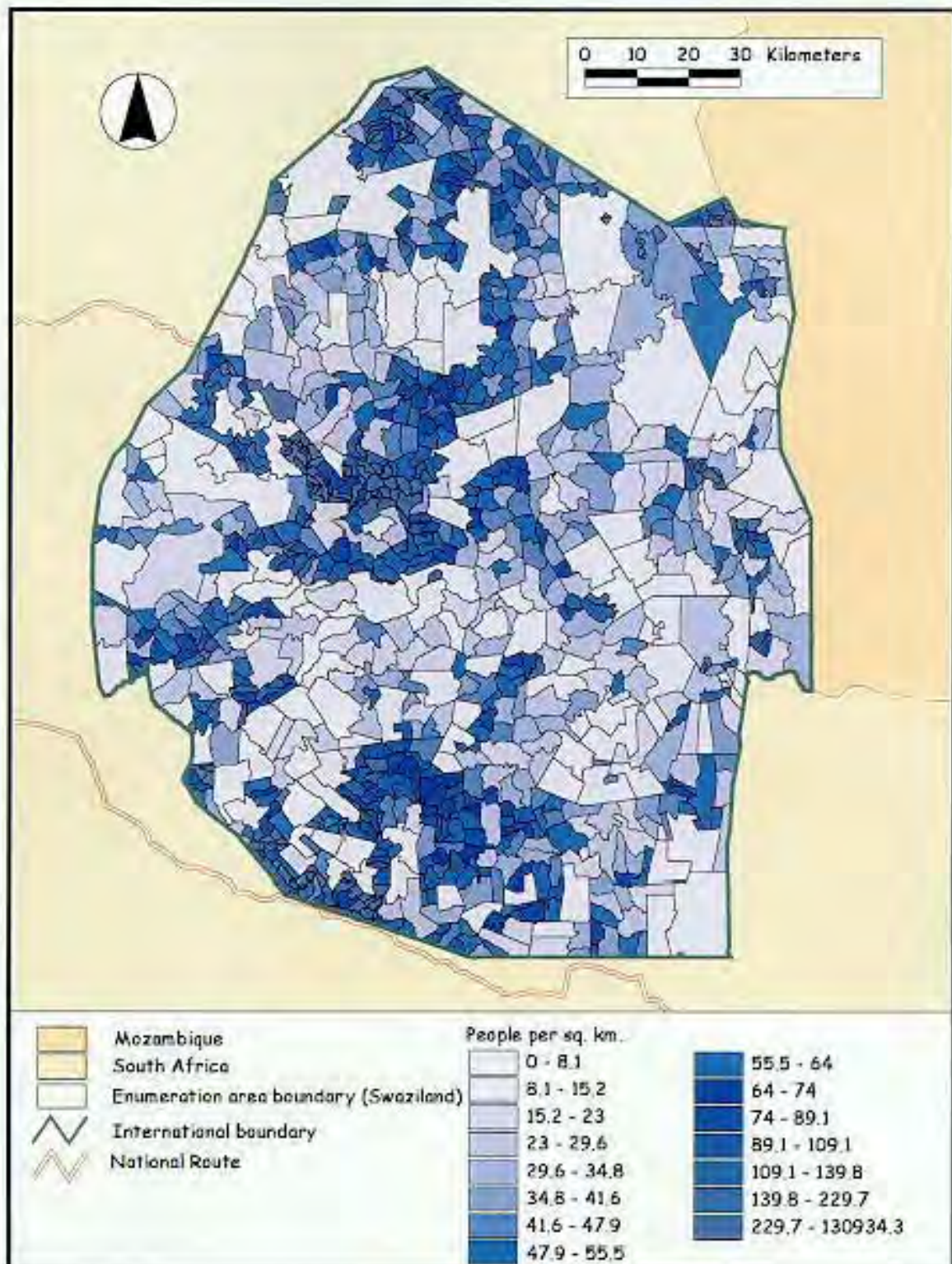


Figure 3.16: Total population density per enumeration area (1986)

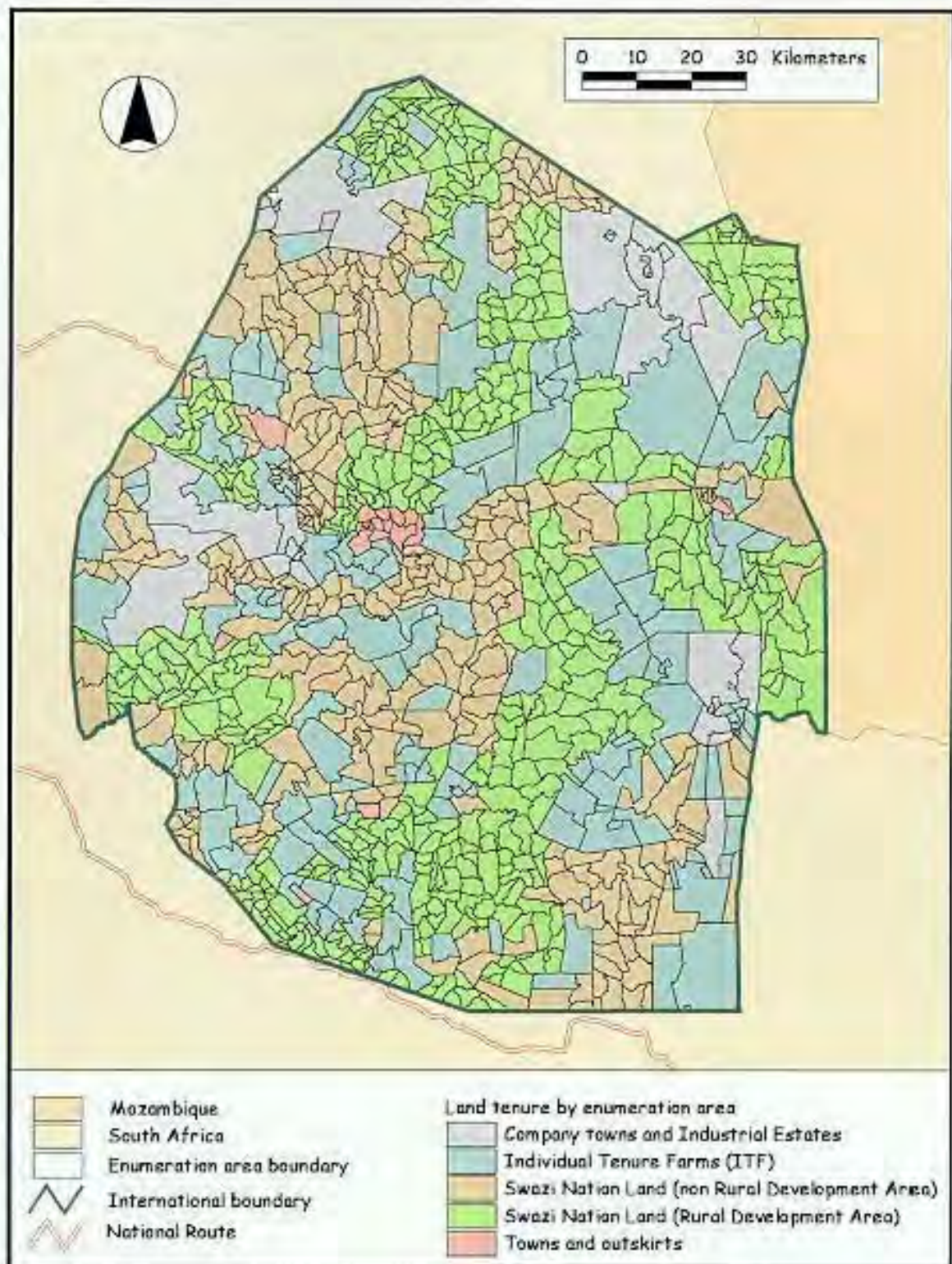


Figure 3.17: Land Tenure by enumeration area (1986)

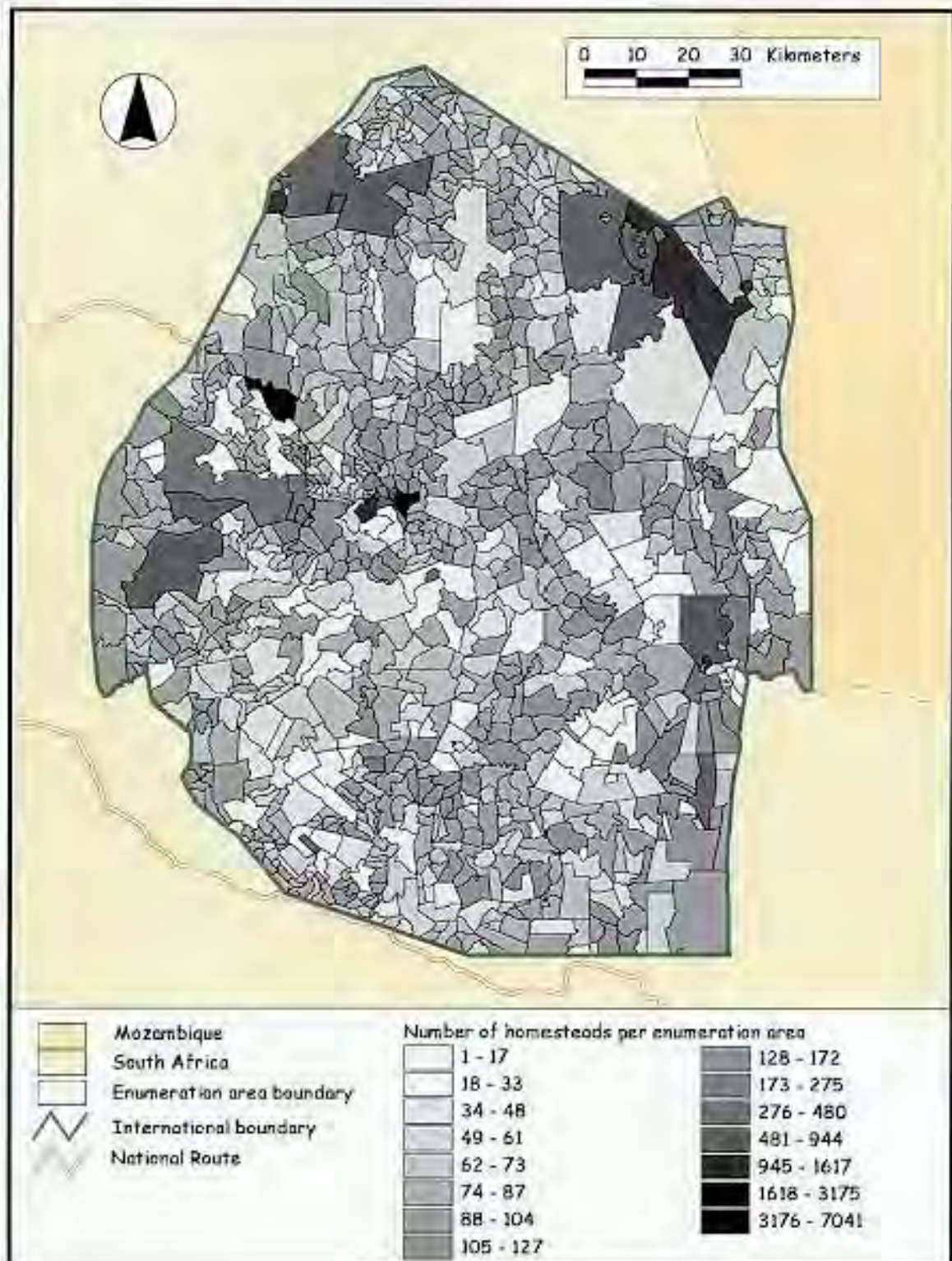


Figure 3.18: Number of homesteads per enumeration area (1986)

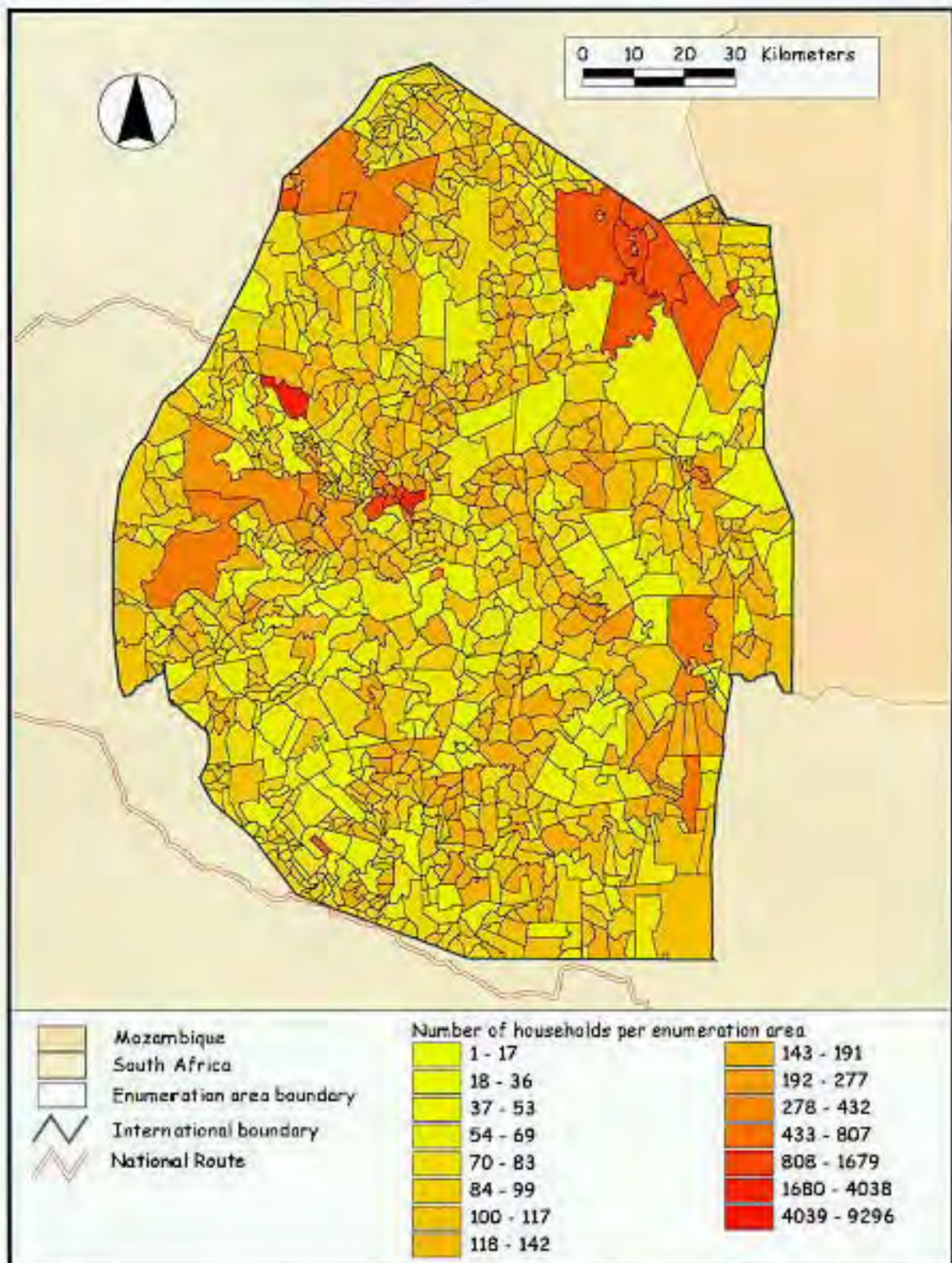


Figure 3.19: Number of households per enumeration area (1986)

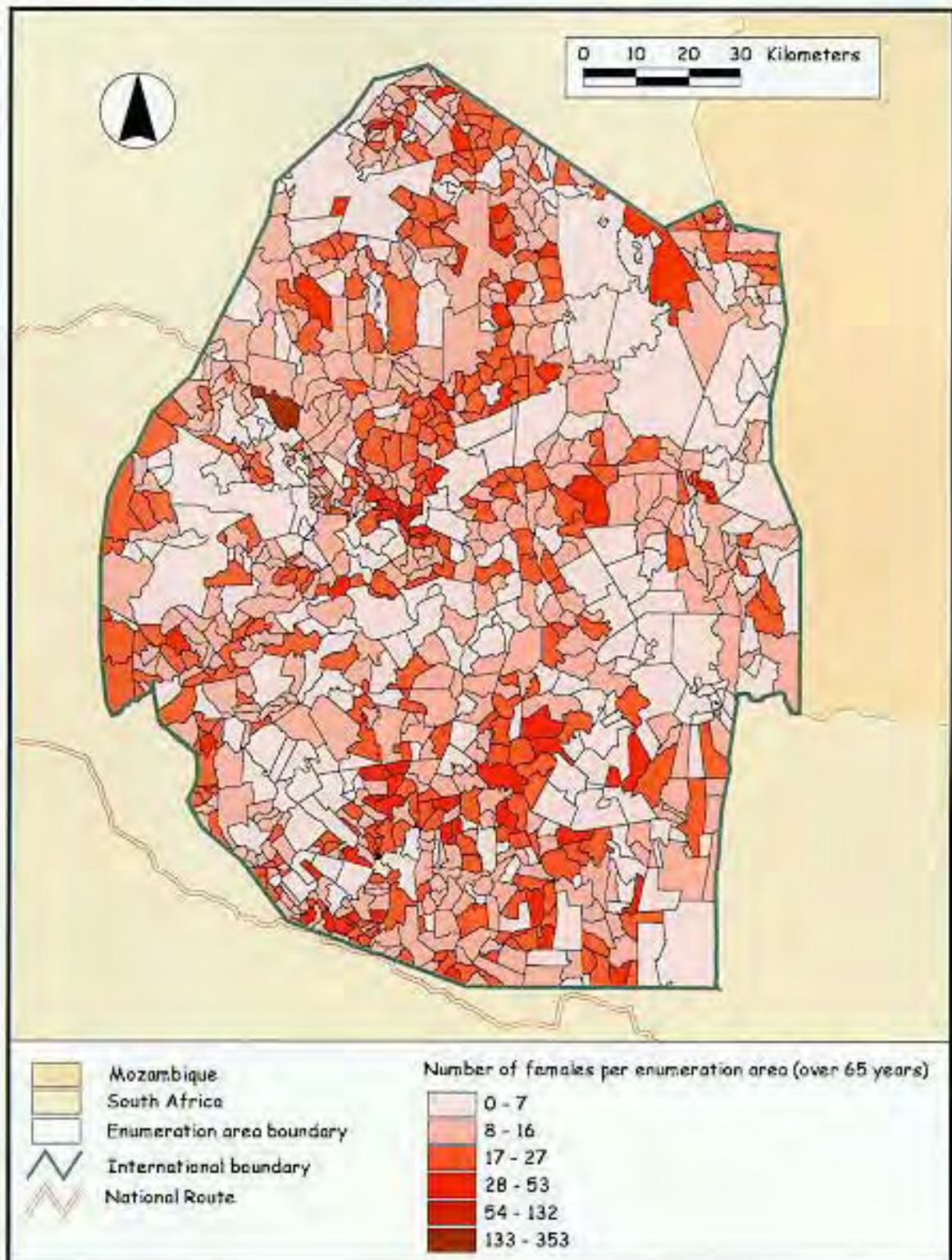


Figure 3.20: Number of females per enumeration area over the age of 65 (1986)

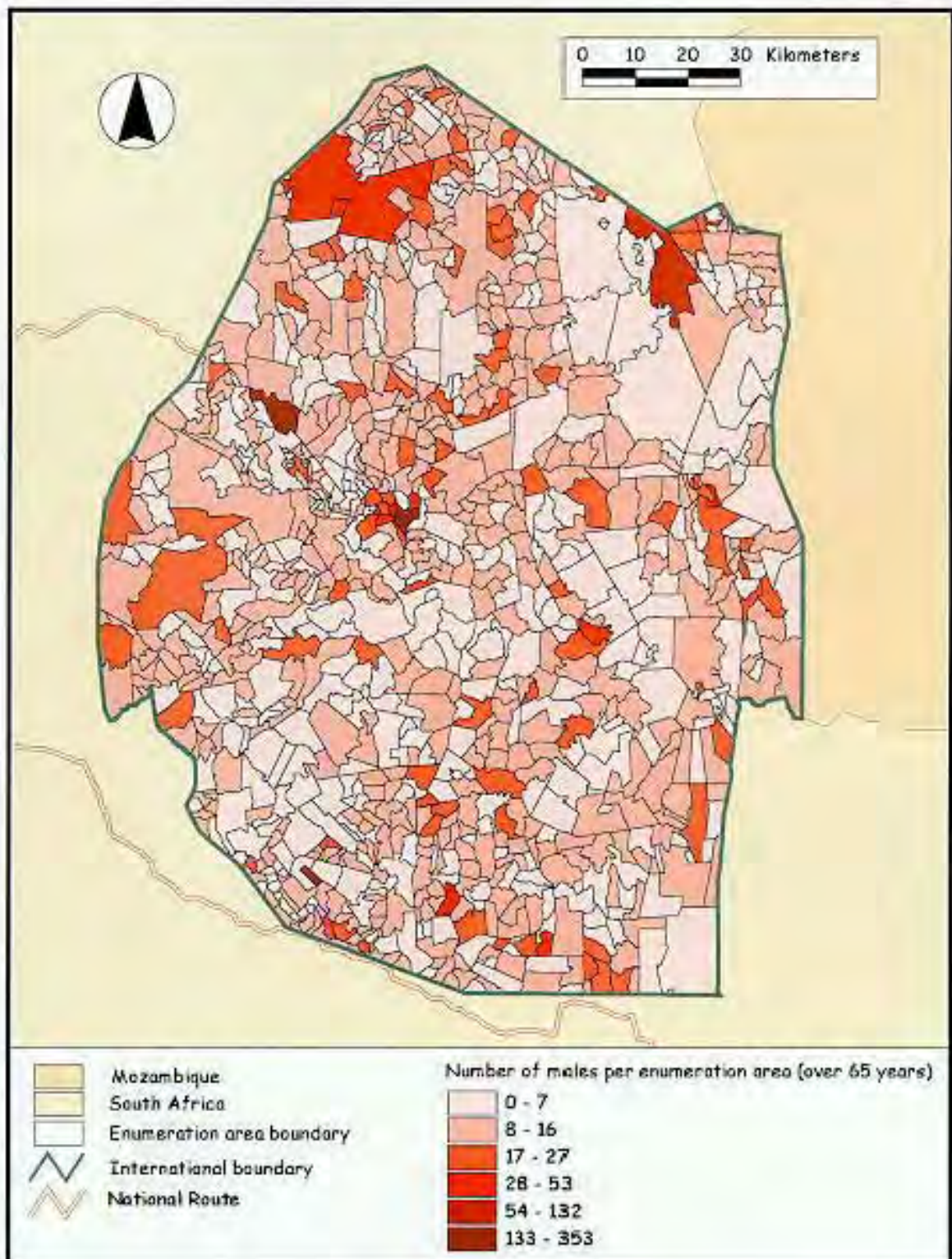


Figure 3.21: Number of males per enumeration area over the age of 65 (1986)

3.8 Capturing additional covers

3.8.1 The roads (1:50 000 source map)

The roads were captured from the 31 1:50 000 map sheets. Arc ids were decided upon for each road type, for example an id of 1 was assigned to the main roads, an id of 3 to the secondary roads, an id of 4 to the other roads and an id of 9 to the railway line. Initially, bridges and tunnels were going to be indicated by using a different user id. The scale of the base maps however did not warrant inclusion of these features.

Each road cover was cleaned to a fuzzy tolerance of 0.3000000 and a dangle tolerance of 0.1000000. The dangle tolerance is set so that small arcs such as slip roads are not deleted during the CLEAN operation. CLEAN "removes dangling arcs that are shorter than the dangle length" (ESRI, 1993: Glossary-8). The snap distance for each cover was set at 0.001" and the GRAIN tolerance was set at 0.03". SPLINE "smooths or generalizes all currently selected arcs using the GRAIN tolerance" (PC ARCEDIT Users Guide, 1990: SPLINE-1) and the command was carried out on those covers with curved arcs e.g. forest boundaries. The GRAIN tolerance is a measurement of the distance that the vertices on an arc are apart, therefore "if the vertices on the arc are farther apart than the GRAIN tolerance, vertices will be added, thereby smoothing the arc" (PC ARCEDIT Users Guide, 1990: SPLINE-2).

Before mapjoining the roads, each of the covers had to be transformed. The master tic file did not have enough tic points to cover the area inside the country boundary, so tic points 85 to 107 were added. The covers were joined using the command EDGEMATCH. Keeping note of the covers became very important to avoid confusion. Cov1 for example was the label given to the edgematched and mapjoined road maps 1, 2 and 3. Having joined the maps into groups like this, the larger groups were then edgematched with each other and subsequently joined. The process looked something like this:

```
EDGEMATCH    cov1 cov2
              cov3 cov2
              cov10 cov2
              cov8 cov2
              cov8 cov3          MAPJOIN cov4 (cov1,2,3,8)
EDGEMATCH    cov10 cov1
```


	cov10 cov8	MAPJOIN covg (cova, cov10)
EDGEMATCH	cov4 cov5	
	cov6 cov5	MAPJOIN covb (cov 4,5,6)
EDGEMATCH	cov7 cov9	MAPJOIN covc (cov7,9)
EDGEMATCH	covb covc	MAPJOIN covd (covb, covc)
EDGEMATCH	covd covg	MAPJOIN roads (covd covg)

The edgematching process was a tedious one, as numerous road sections had been omitted by accident. The missing road pieces only became apparent when the maps were joined together and sections were clearly missing. In cases like this the map was taped onto the digitizing tablet again and the arcs were added. The cover was built, matched and joined all over again. The same process was carried out for each of the coverages. The command APPEND instead of MAPJOIN was used for the point covers such as schools and hospitals. The final road coverage can be seen in **Figure 3.22**.

To be sure that each of the processes had been completed, it became necessary to fill out a form shown in **Table 3.4** below.

Cover	Clean	Build	Edit	Build	Transform	Build	Edge-match	Mapjoin	Append
Fores	U	U	U	U	U	U	U	U	X
Fores1	U	U	U						

Table 3.4: An example of the operations form used during data capture (This form indicates that a polygon cover was being created; the covers were joined using MAPJOIN rather than APPEND)

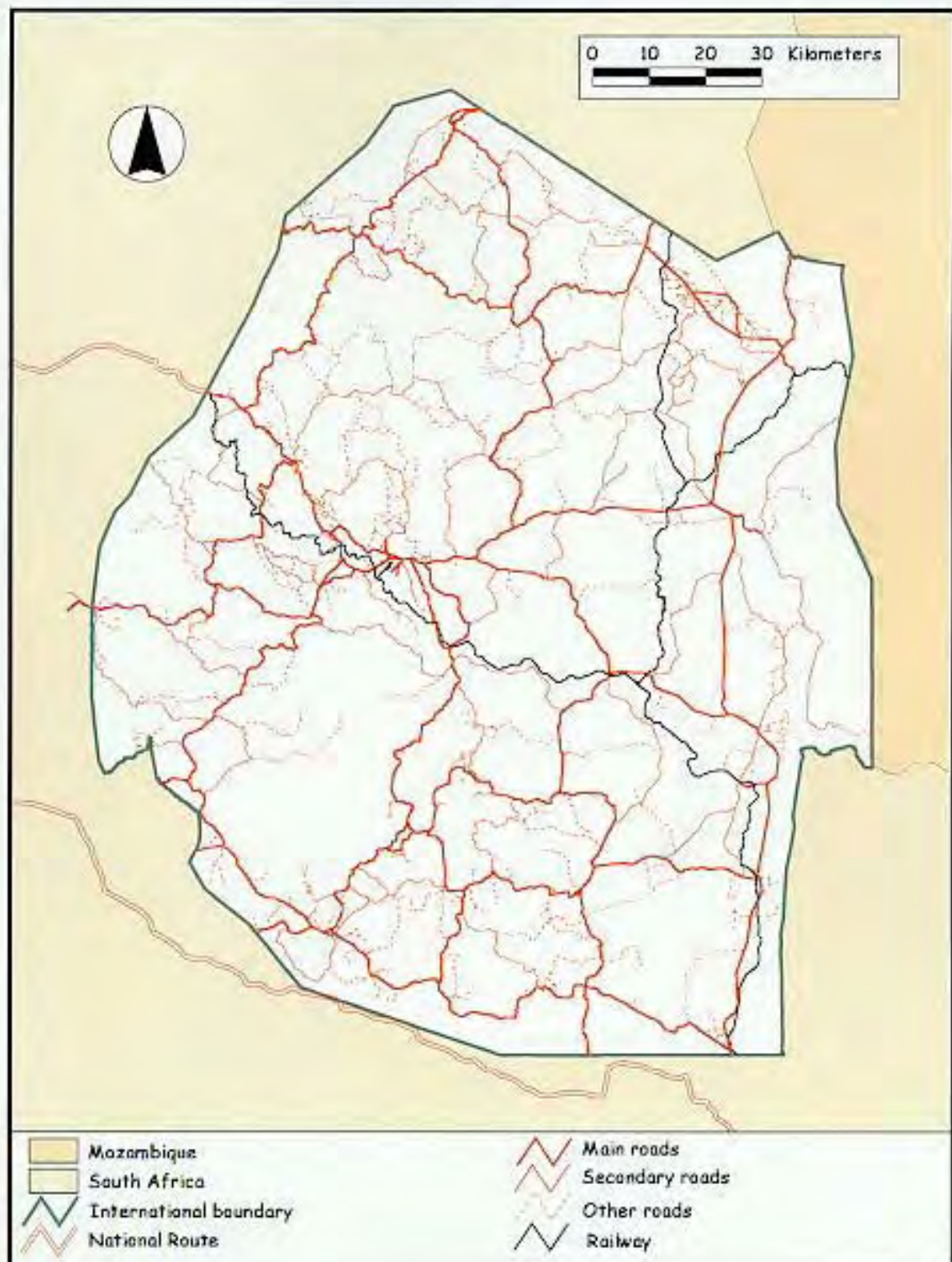


Figure 3.22: Road coverage for Swaziland (1991)

3.8.2 Creating a sample from the Bird Atlas of Swaziland (Parker,1994)

The Bird Atlas of Swaziland (Parker,1994) is the result of seven years of dedicated bird watching and recording in Swaziland by Vincent Parker with help provided by several amateur birders. The coverage is apparently more detailed than for any other area in the southern African region (Parker,1994:ix). "Before the publication of this atlas, virtually no information had ever been published on the great variety of bird life in Swaziland" (Forsyth Thompson,1994:ix). It was considered appropriate to include data from a significant indigenous study. Selecting some of the data from Parker's atlas and incorporating it in the *Population-Environment Atlas of Swaziland* was hoped to serve as an example of the type of data that could be included in a national atlas.

The first step was to decide the best way to input the data and represent it. The atlas has data on geographical distribution, abundance and seasonality of bird species which were known to have occurred in the country between 1985 and 1991. Parker (1994) selected a 1/8 degree grid "for which it was practically possible to compile adequate data for each grid unit during the time available for the project." (Parker,1994:1).

It was decided that the 1/8 degree grid for the country would be created in PC ARC/INFO. The cell size of the grid was calculated by finding out the number of degrees and minutes on the x and y axes of the 1:250 000 topological map. To create the 1/8 degree grid, the x axis required 12 columns and the y axis required 14 rows.

y axis

$$27^{\circ} 20' - 25^{\circ} 40' = 1^{\circ} 40'$$

(y axis covers 1 40')

$$1^{\circ} 40' = 100'$$

$$100 / 14 = 7.142857'$$

x axis

$$32^{\circ} 10' - 30^{\circ} 45' = 1^{\circ} 25'$$

(x axis covers 1 25')

$$1^{\circ} 25' = 85'$$

$$85 / 12 = 7.083333$$

The calculations showed the resulting grid cell had to be 7.1428' by 7.0833' to create the 1/8 grid which is "roughly square"(Parker,1994:1).

The grid was opened in ARCEDIT and although it covered the entire screen, the 84 tic points for Swaziland sat in the lower left hand corner. At this stage further problems were experienced with the hardware. The computer hung every time it reached a certain point. The coverage was moved to a computer with greater memory capacity, and no more hardware problems were experienced.

In trying to solve the problem, it was thought that the solution might be found by projecting the grid from a geographic to an albers projection. This did not work at all, resulting in the grid becoming stretched and tilted to the right. It was through a process of trial and error and elimination, that the possibility of the problem being related to cell size was considered. One simple step had been omitted. The units had been calculated in minutes and needed to be converted to decimal degrees.

1 minute = 1.666667 of a degree (decimal degrees)

$7.142857' \times 1.666667 = 11.9047640$ ($/100 = 0.119047640$ to get it into fractions of a minute)

$7.08333' \times 1.666667 = 11.8055524$ ($/100 = 0.118055524$ to get it into fractions of a minute)

The grid was recreated with the new cell dimensions. Viewing the result in ArcView, the problem appeared to have been solved. The grid was then opened in ArcView 3.0 and overlaid with the enumeration areas; both coverages were overlaid successfully. Statistical data relating to the number of bird species was recorded in the attribute table. Overlaid with the enumeration areas, the resulting display looked very coarse. Attempts at joining the enumeration area tables with that of the bird atlas grid however did not improve the representation. The grid was ultimately clipped to the international boundary (see **Figure 3.23**).

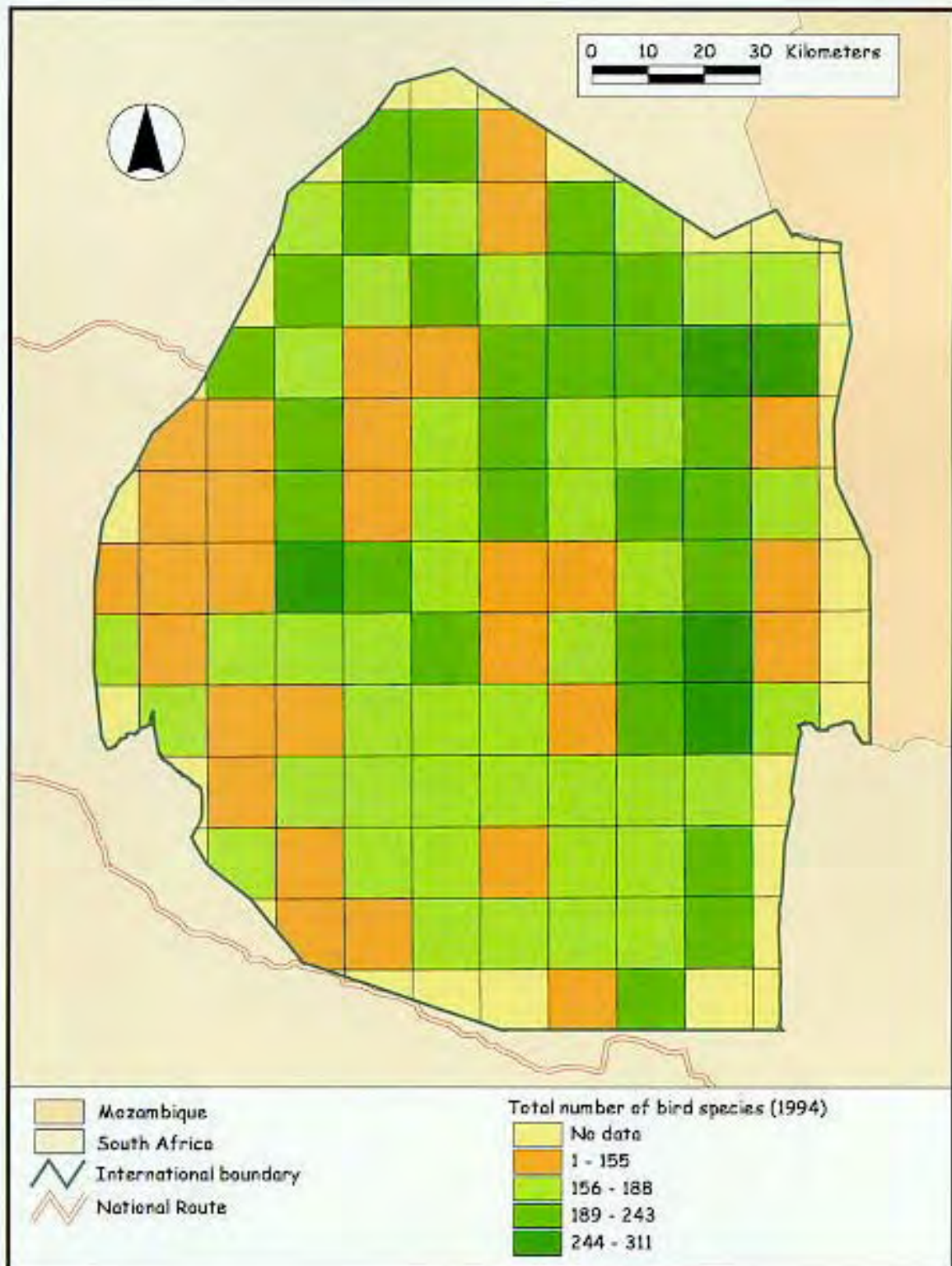


Figure 3.23: Total numbers of bird species for Swaziland (1994)

3.8.3 Creating a grid for Swaziland

To help with orienting the user, it was decided that a 5' by 5' grid indicating lines of latitude and longitude would be created for Swaziland which could be overlaid with the enumeration areas or any subsequent covers for the country. The grid cell size was calculated as for the bird species grid. This time, 20 rows and 17 columns were needed.

$$100 / 20 = 5'$$

$$85 / 17 = 5'$$

$$5' \times 1.666667 = 8.333335 \text{ } (/100 = 0.08333335) - \text{to get it into fractions of a minute}$$

The grid squares had to be 0.08333335' by 0.08333335'. The grid overlaid the enumeration areas without any apparent problems.

3.8.4 Towns (1:250 000 source map)

Thirty nine towns were captured as a point cover from the 1:250 000 topographical map. The names of the towns were fed into the attribute table in ArcView 3.0, allowing the user to auto label the coverage if so desired. The towns of Piggs Peak, Mbabane, Lobamba, Bhunya, Manzini, Simunye, and Malkerns all have photographs hotlinked to them. The images either show the towns themselves, or areas of interest near by. The final coverage can be seen in **Figure 3.24**.



Figure 3.24: Towns of Swaziland (1989)

3.8.5 Schools (1:50 000 source map)

All school buildings indicated on the 1:50 000 map series were captured as a point cover. The covers were transformed and appended. The final cover can be seen in **Figure 3.25**.

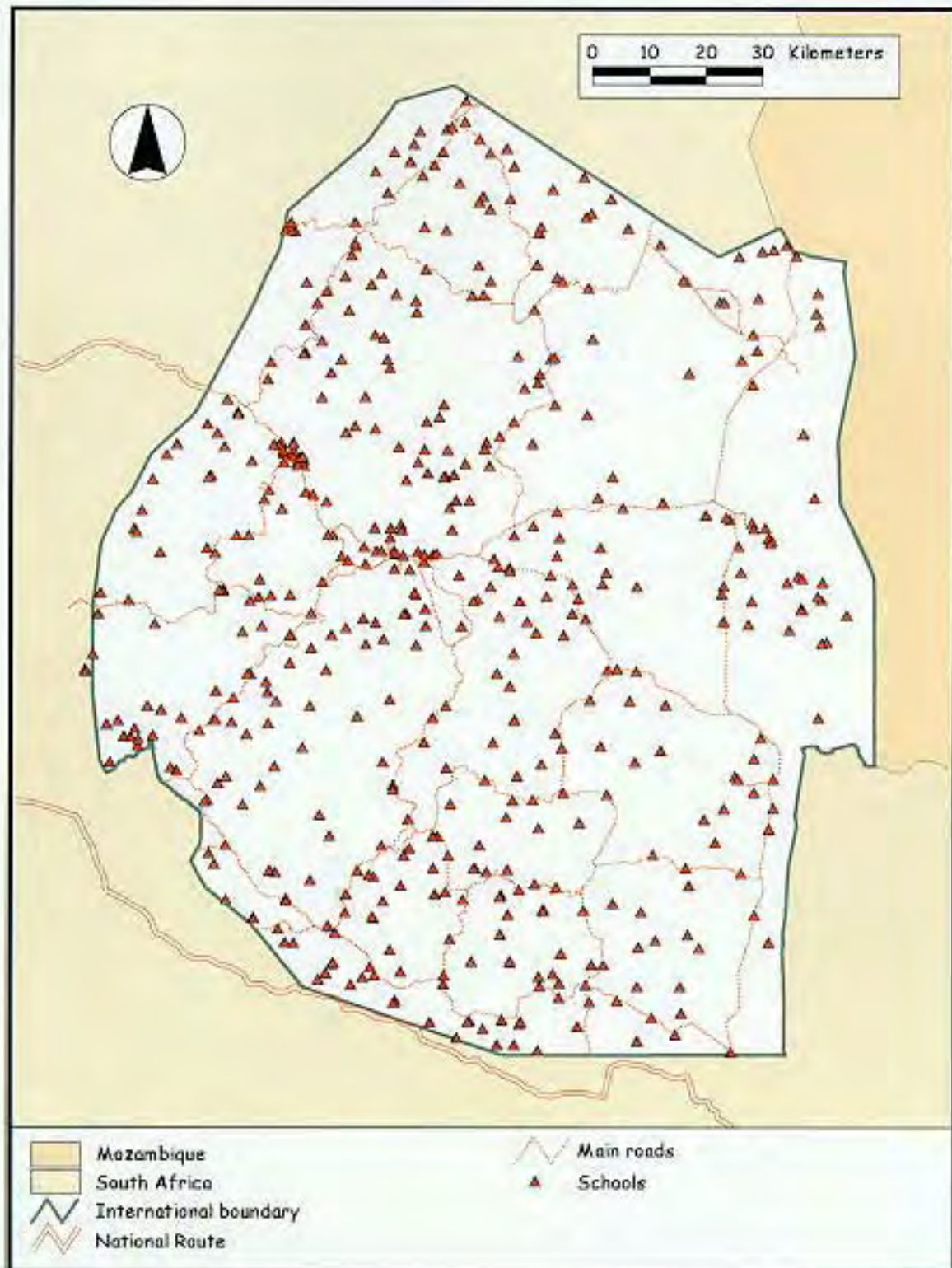


Figure 3.25: Schools in Swaziland (1991)

3.8.6 Electricity Transmission Lines (1:50 000 source map)

The electricity transmission lines were captured as an arc cover from the 1:50 000 map series, edited, transformed, edgematched and mapjoined. The final coverage can be seen in **Figure 3.26**.

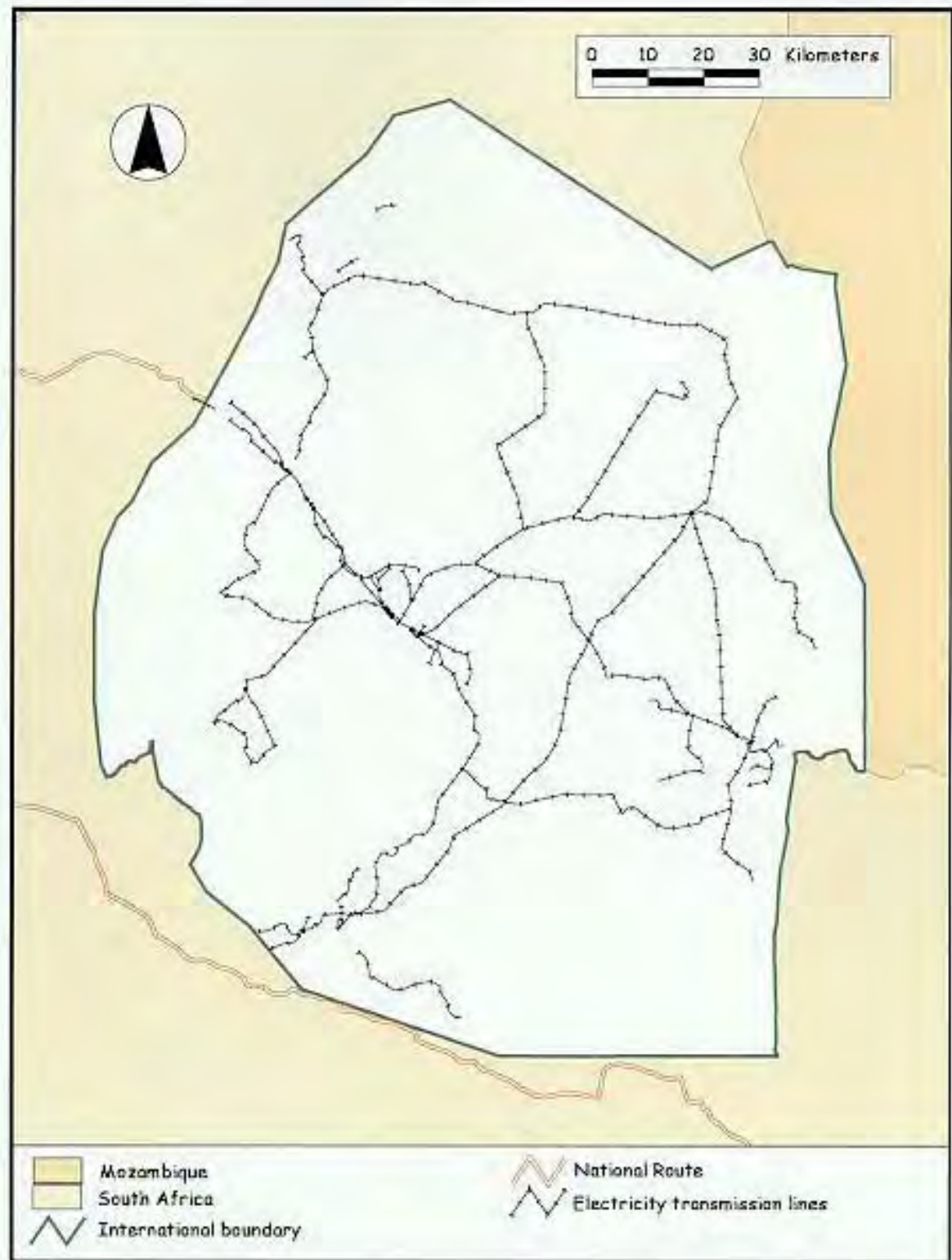


Figure 3.26: Electricity transmission lines (1991)

3.8.7 Forests (1:50 000 source map)

The forests cover was captured as a polygon cover from the 1:50 000 maps. Although very time consuming due to the number of small polygons which had to be captured and edited (200 polygons) and the presence of firebreaks in the man made plantations of Usutu and Nhlangano, few problems were experienced with this cover. The cover can be seen in **Figure 3.27**.

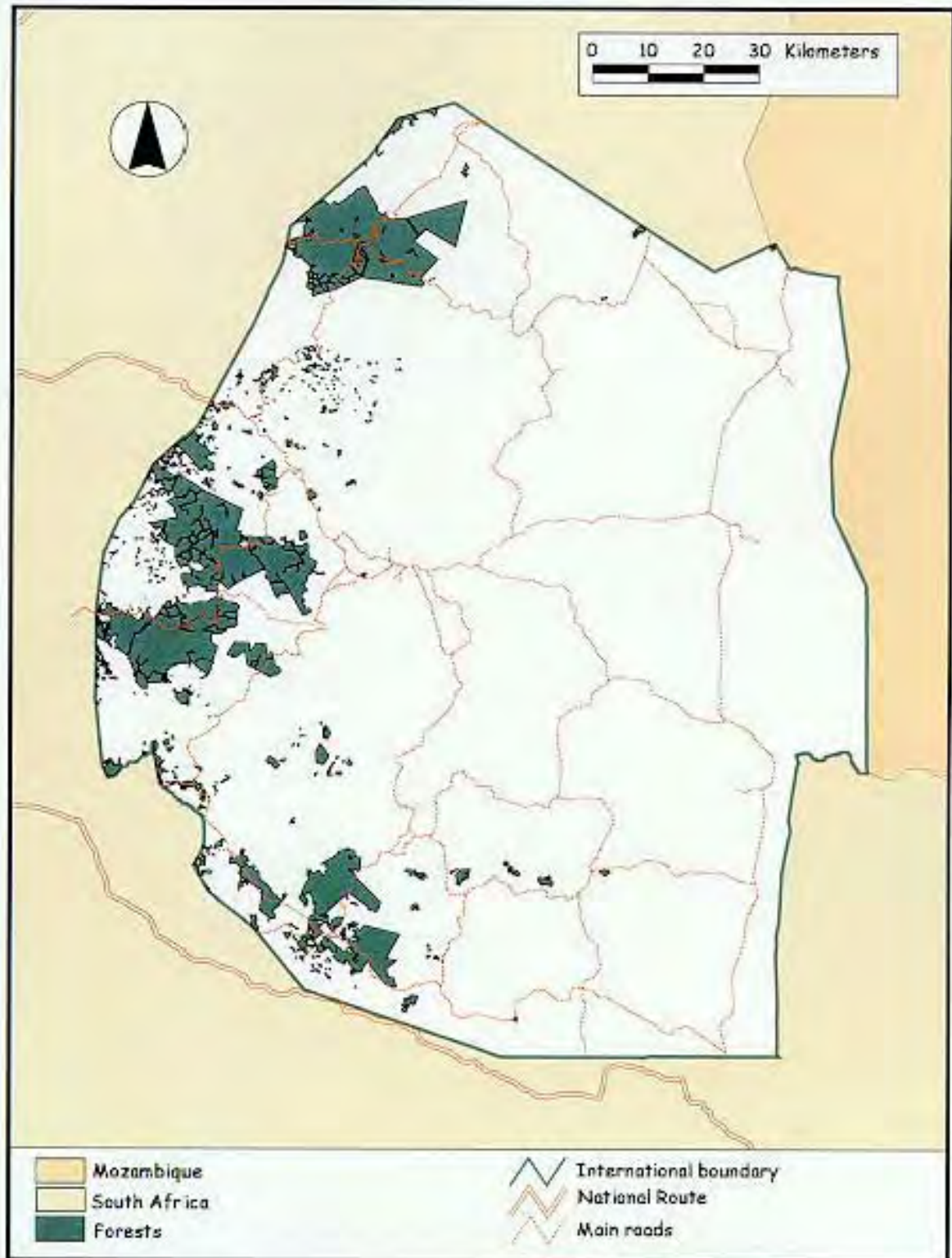


Figure 3.27: Forests of Swaziland (1991)

3.8.8 Nature and game reserves (1:50 000 source map)

The nature and game reserves were captured as a polygon cover from the 1:50 000 maps. The cover can be opened in ArcView 3.0 according to reserve name. Hlane park has an image hotlinked to it for viewing by the user if so desired. The cover can be seen in **Figure 3.28** overlaid with the mines.

3.8.9 Mines - used and unused (1:50 000 source map)

The mines were captured from the 1:50 000 maps as a point cover, and can be seen in **Figure 3.28** overlaid with the country's nature and game reserves.

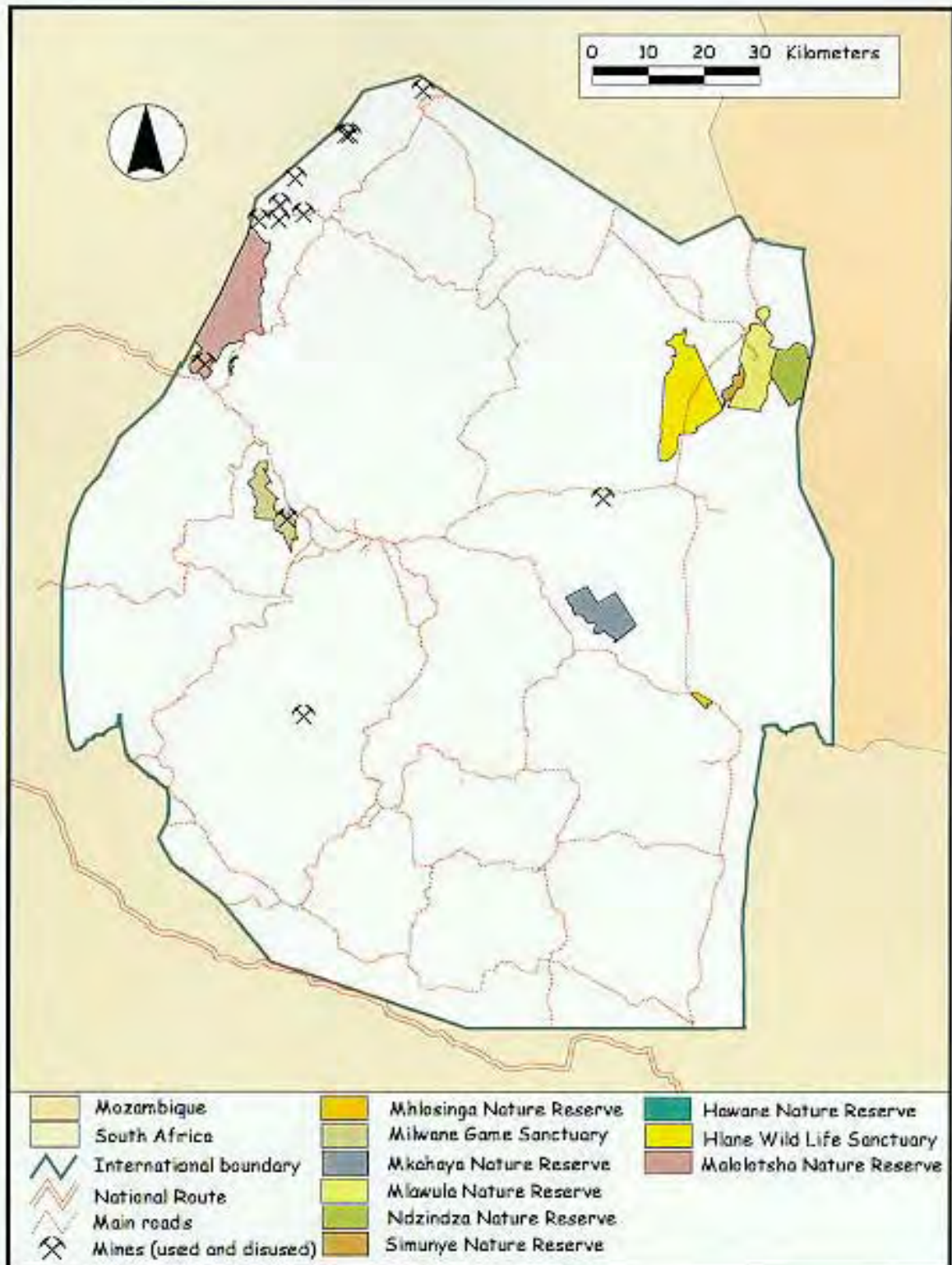


Figure 3.28: Nature reserves and mines (used and unused) (1991)

3.8.10 Tourist covers (1:50 000 source map)

All hotels, motels, lodges and border posts depicted on the 1:50 000 map series were captured as a point cover and can be seen in **Figure 3.29**. An image has been linked to the hotels in the Ezulwini Valley for the user to view. The names and times of opening and closing of the border posts can be viewed if the user wishes. Golf courses, airstrips, the main airport, the hot springs in the Ezulwini Valley, stables, the main royal residence, parliament and the national museum are all visible on **Figure 3.30**. The main waterfalls have been included, with an image hotlinked to the Phophonyane waterfalls. The famous Sebebe Rock has been marked and can be viewed through a hotlinked image as well. The main dam for water sports has been captured. The golf courses, airstrips, airport and water sports dam are available as polygon or point covers.

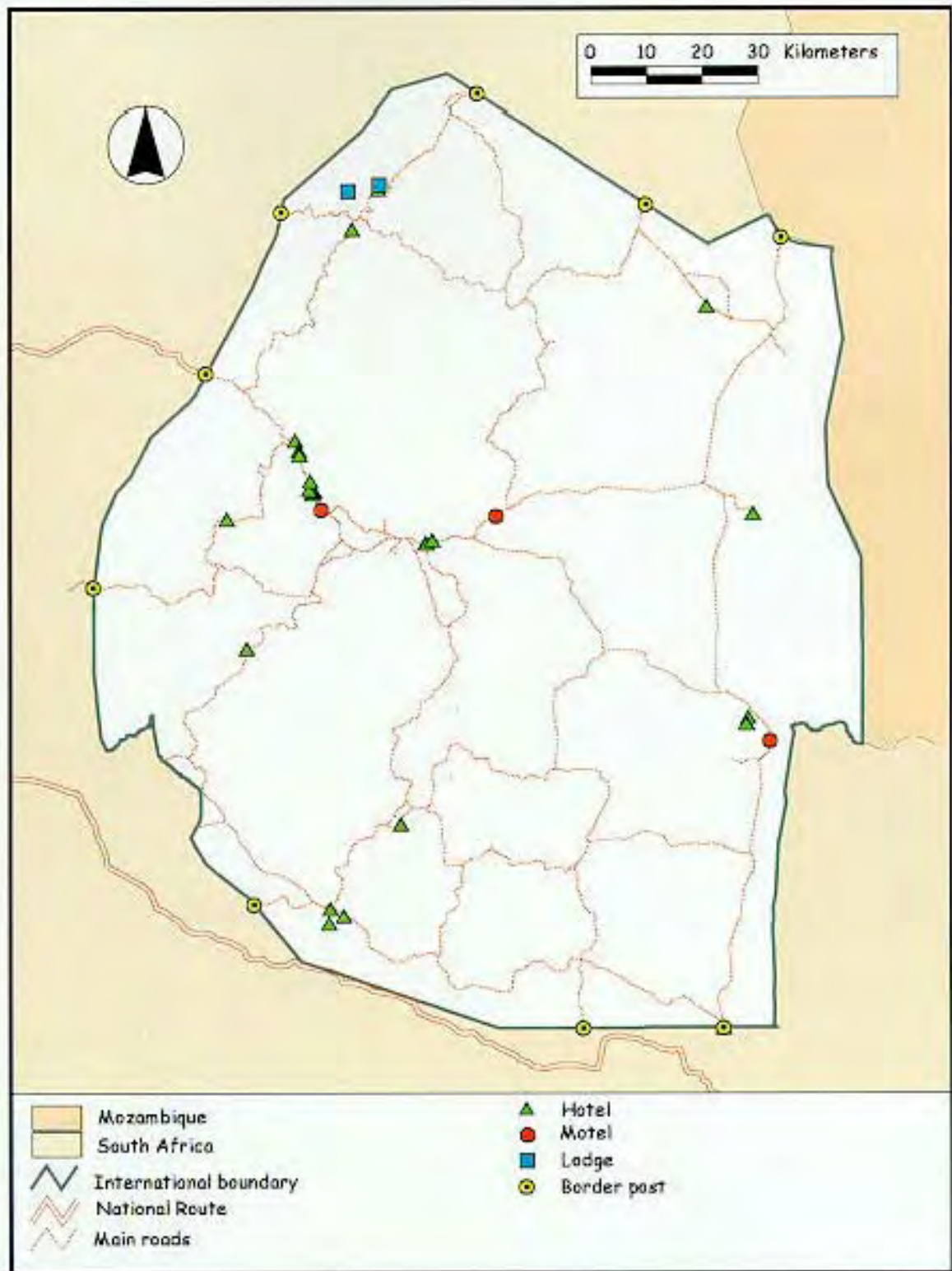


Figure 3.29: Accommodation and entry points in Swaziland (1991)

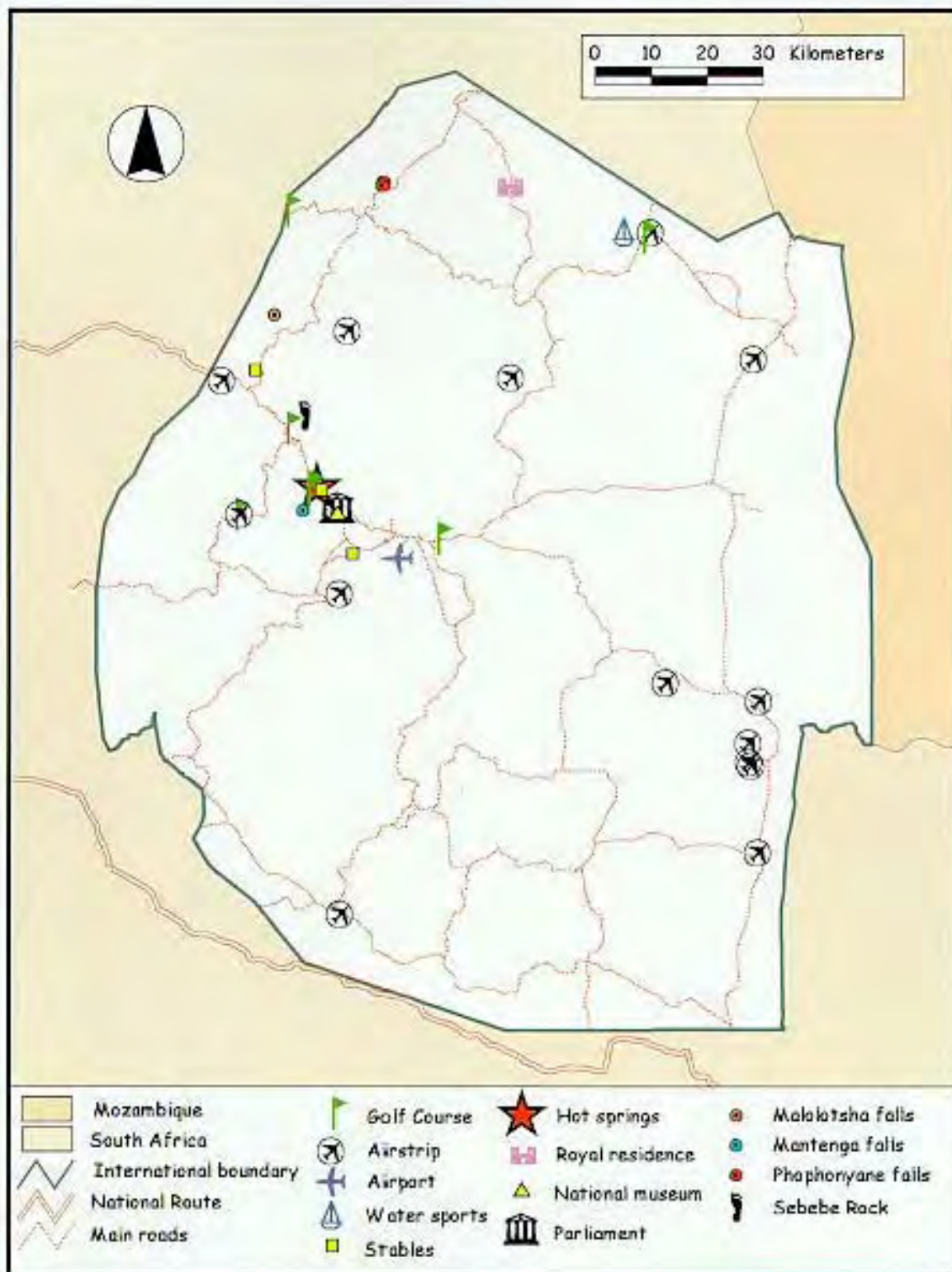


Figure 3.30: Tourism interest areas (1991)

3.8.11 Medical cover (1:50 000 source map)

All hospitals, clinics and health centres indicated on the 1:50 000 map series were captured as a point cover. In ArcView 3.0, the cover can be opened so that the three categories are automatically visible in the legend. The final cover can be seen in **Figure 3.31**.

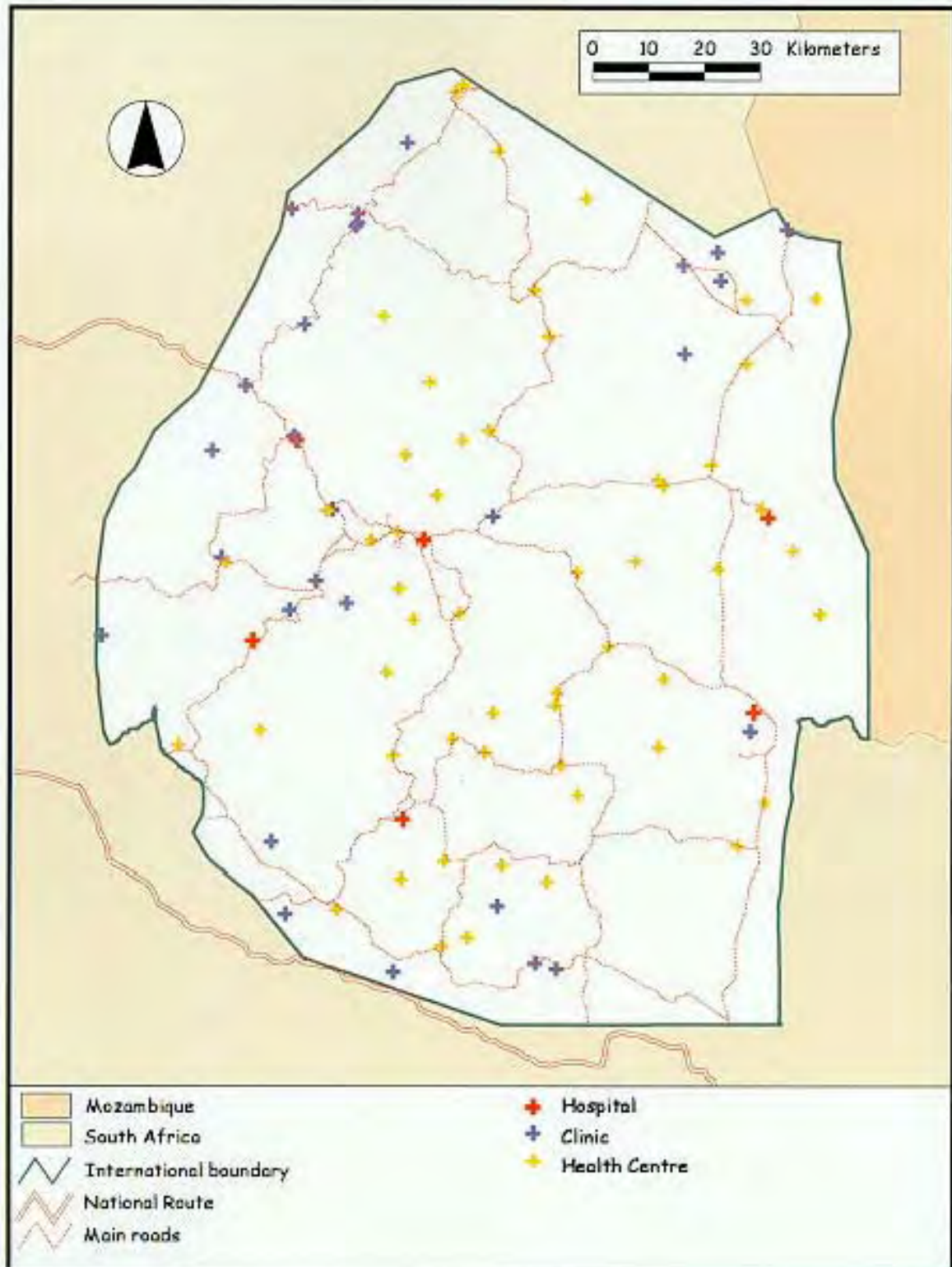


Figure 3.31: Hospitals, clinics and health centres in Swaziland (1991)

3.8.12 Post Offices and Police Stations (1:50 000 source map)

All post offices and police stations were captured as a point cover as seen in **Figure 3.32**.

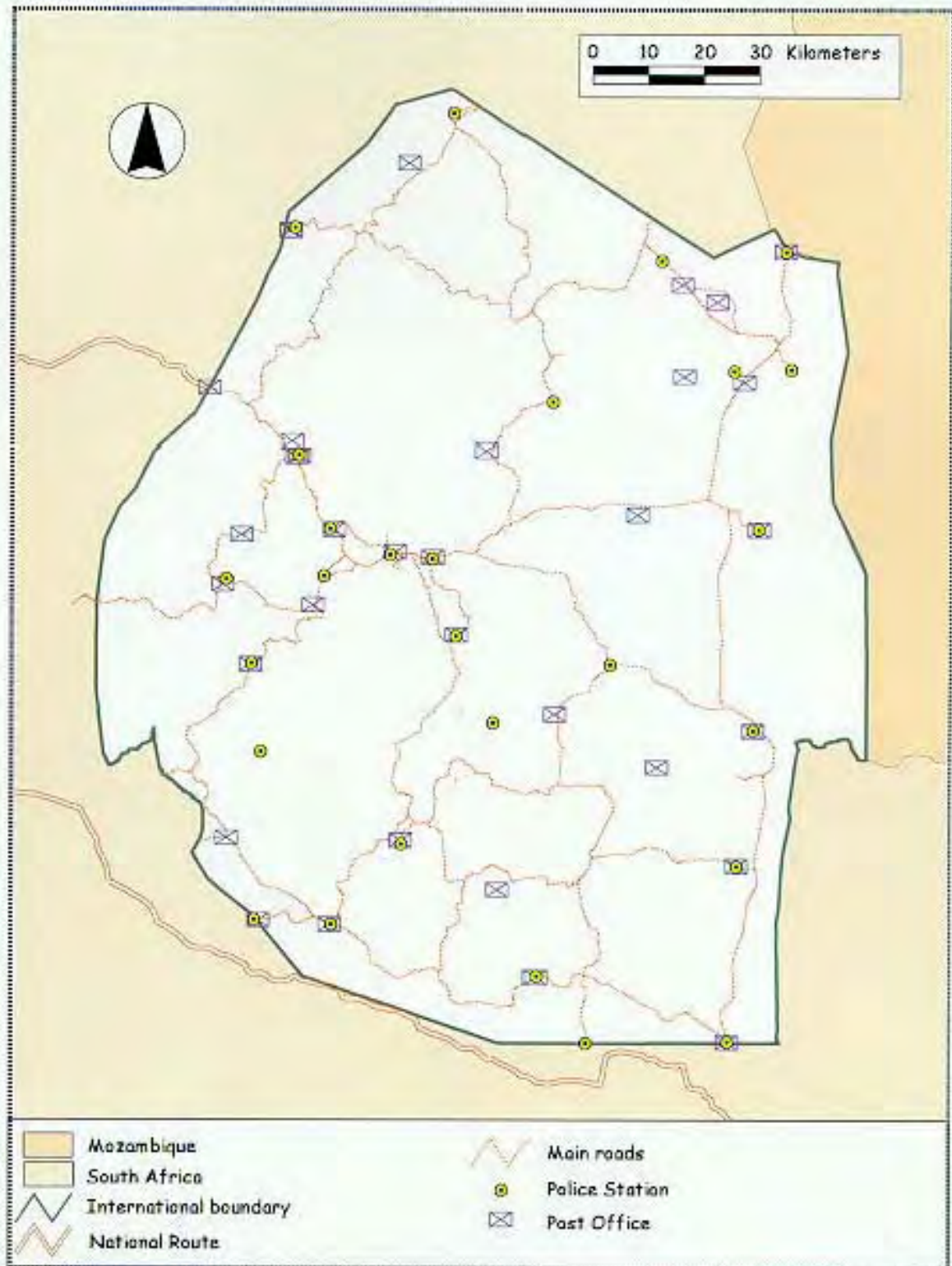


Figure 3.32: Post offices and police stations in Swaziland (1991)

3.9 Delivery of IDRISI files from Swaziland

During the first meeting with the Department of Land Use and Planning in January 1998 it was established that they had several environmental coverages for Swaziland. These coverages had been created with an older DOS version of IDRISI in cooperation with the Food and Agricultural Organisation (FAO) (Van Waveren, 1998:pers.comm.). Permission to gain access to these covers was obtained at the end of May 1998. The main concern at this stage was whether or not the covers would be compatible with the covers created with PC ARC/INFO.

When an attempt to open the files was made in IDRISI for Windows, an error message appeared saying "maximum x and y coordinates must be greater than minimum x and y coordinates". The coordinates were on the SA grid system which IDRISI for Windows does not comprehend "because the lowest x, y values are always in the upper right corner of the map" (Van Waveren, 1998:pers.comm.). The coordinates given when asked to describe the file, were:

```
min x: 25 000.0000000
max x: -115 000.0000000
min y: 3025000.0000000
max y: 2840000.0000000
```

Clearly, the minimum x value is greater than the maximum; this is where the program found fault. To rectify the problem, the x and y minimum values were swapped with the x and y maximum values. Image formats supported by ArcView 3.0 were then established. ERDAS was one image that was common to both IDRISI for Windows and ArcView 3.0. The image files had to be exported from IDRISI and to do this, the data type had to be converted from packed binary to byte binary. The files could then be viewed in ArcView 3.0.

The attribute tables for the moisture, thermal, land use, tenure, soils and vegetation maps were edited to allow the user to open each of the covers according to actual rainfall amounts, temperatures, tenure type, soil type and vegetation type. These maps can be seen in **Figures 3.33 - 3.38**.

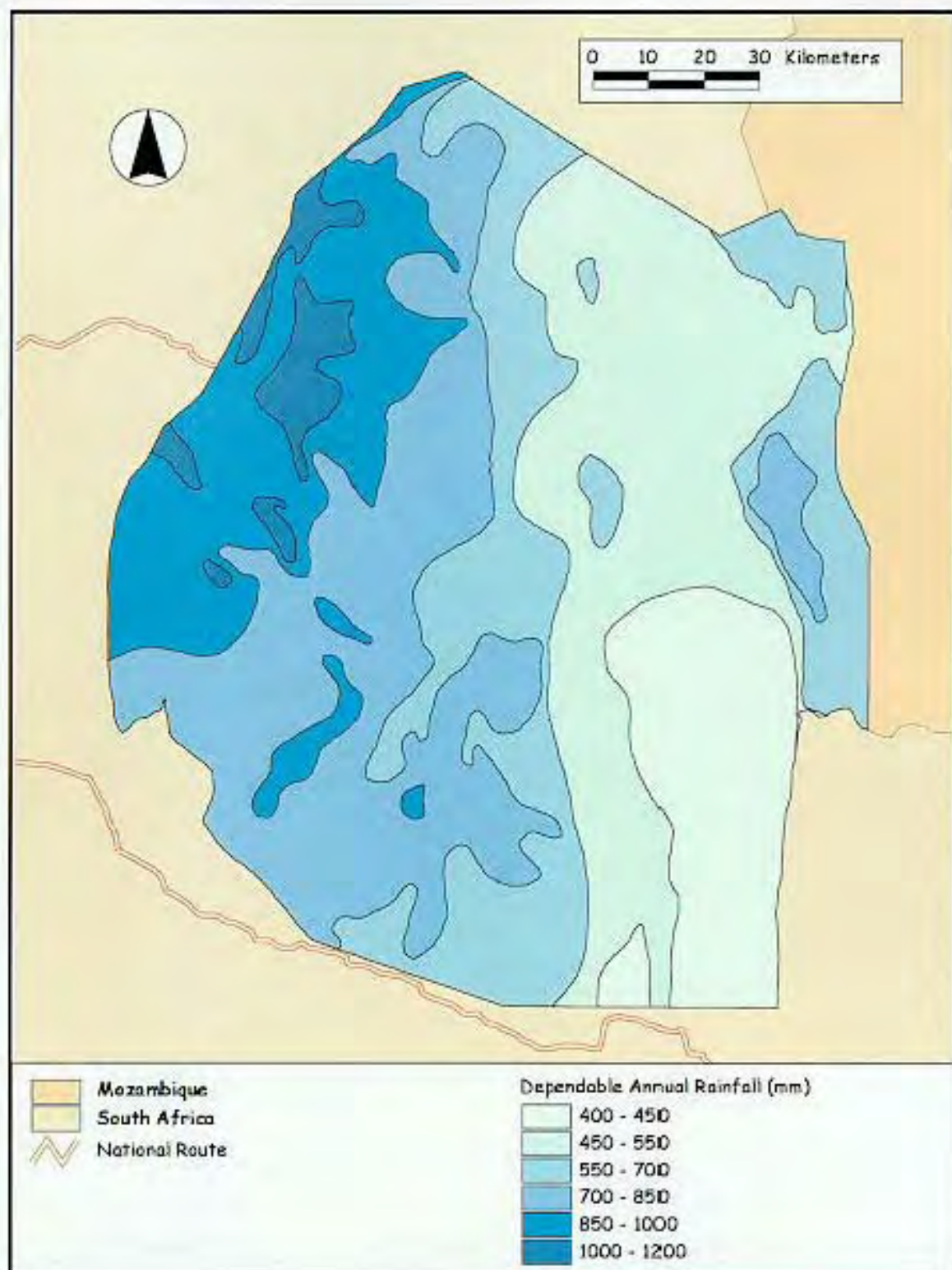


Figure 3.33: Moisture zones (Dept. of Land Use and Planning, Ministry of Agriculture, 1994)

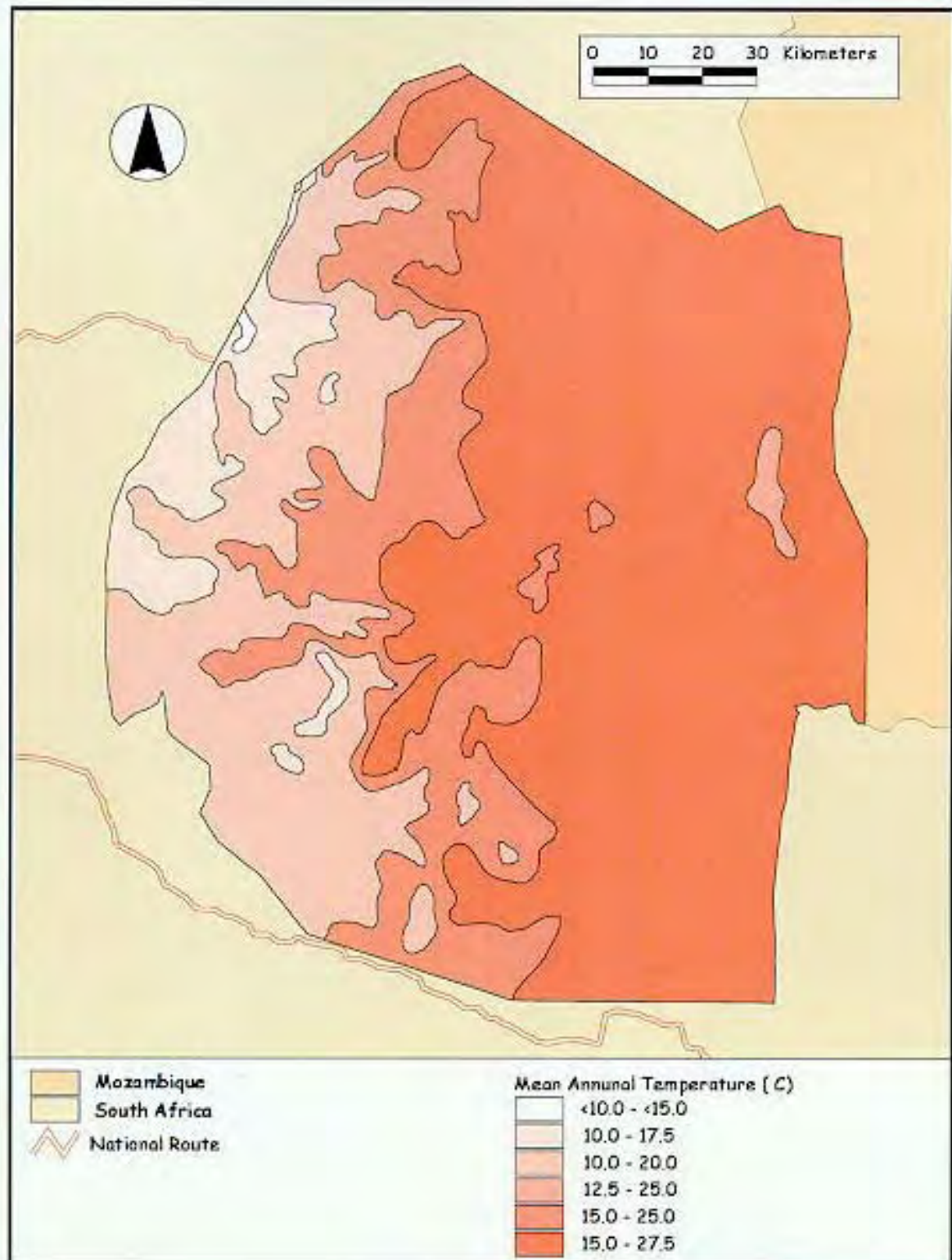


Figure 3.34: Thermal zones (Dept. of Land Use and Planning, Ministry of Agriculture, 1994)

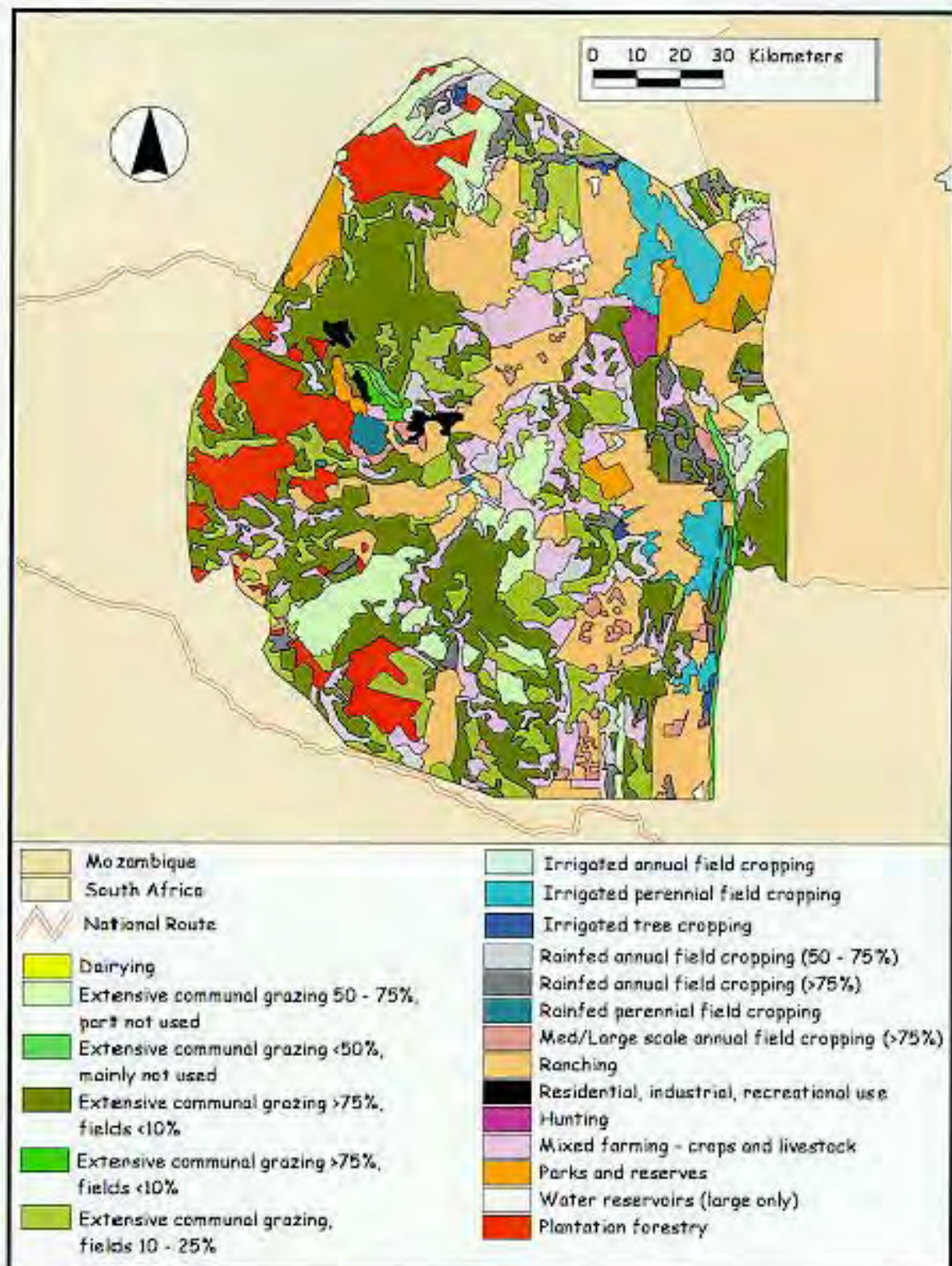


Figure 3.35: Land use (Dept. of Land Use and Planning, Ministry of Agriculture, 1994)

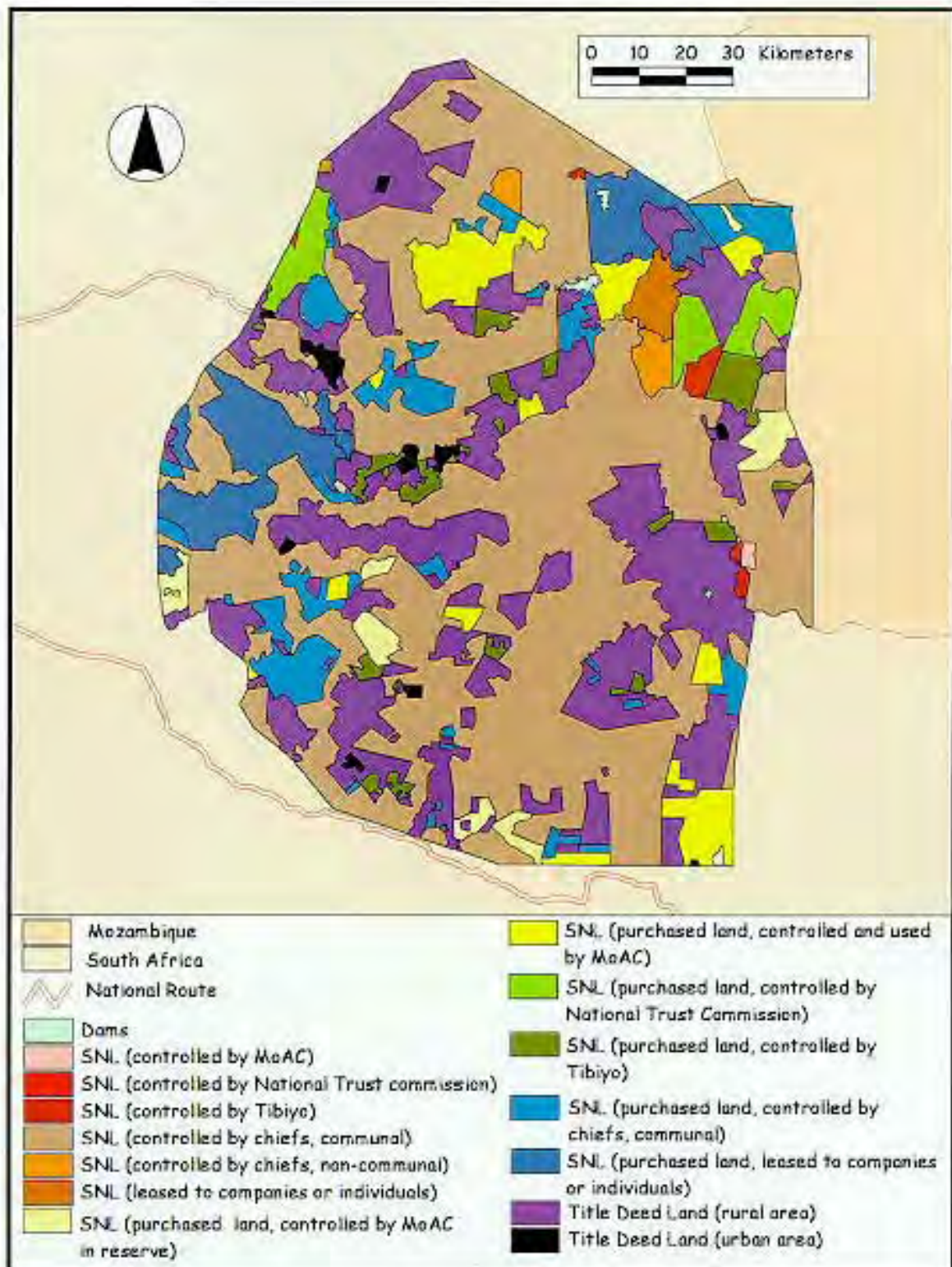


Figure 3.36: Land Tenure (Dept. of Land Use and Planning, Ministry of Agriculture, 1994)



Figure 3.37: Soil types (Dept. of Land Use and Planning, Ministry of Agriculture,1994)

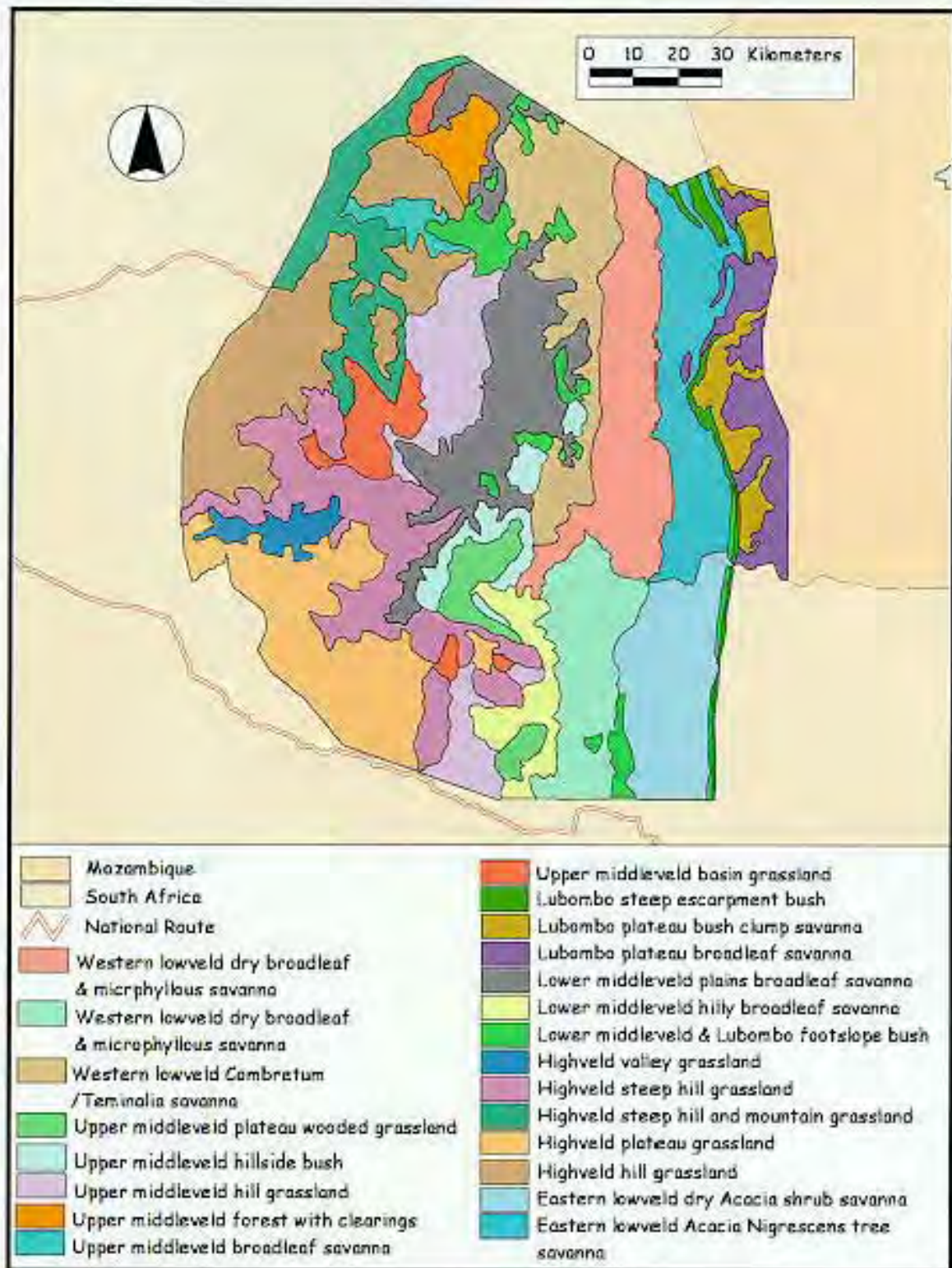


Figure 3.38: Vegetation types (Dept. of Land Use and Planning, Ministry of Agriculture, 1994)

3.10 Digital Elevation Model (DEM) for Swaziland

ComputaMaps in Cape Town was contacted via e-mail from the company's web page on the Internet (<http://map.co.za/maps/dem.htm>) and a DEM for Swaziland was ordered. This DEM is shown in **Figure 3.39**. It was hoped that the image files from the Ministry of Agriculture, the DEM and the data captured in PC ARC/INFO would all overlay. To do this, the converted IDRISI files and the DEM had to be converted to gridfiles whilst in ArcView 3.0.

From this Digital Elevation Model, a generated Triangulated Irregular Network (TIN) was created for the country (see CD-ROM **e:\Atlas\Cover\tin.bmp**). Contours (**Figure 3.40**) and Aspect (see CD-ROM **e:\Atlas\Cover\aspect.bmp**) were also interpolated, concluding step three of the atlas production.

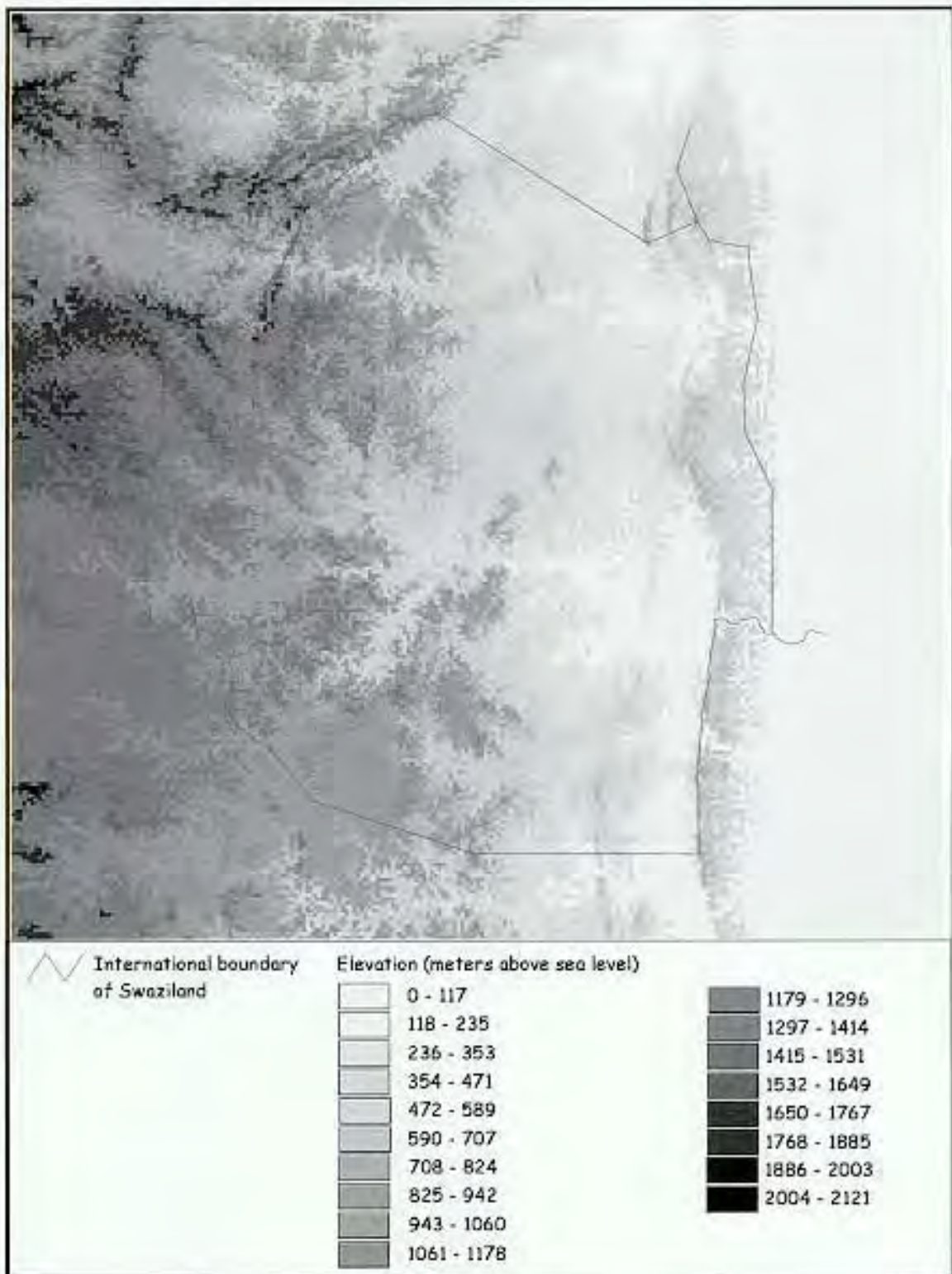


Figure 3.39: Digital Elevation Model of Swaziland

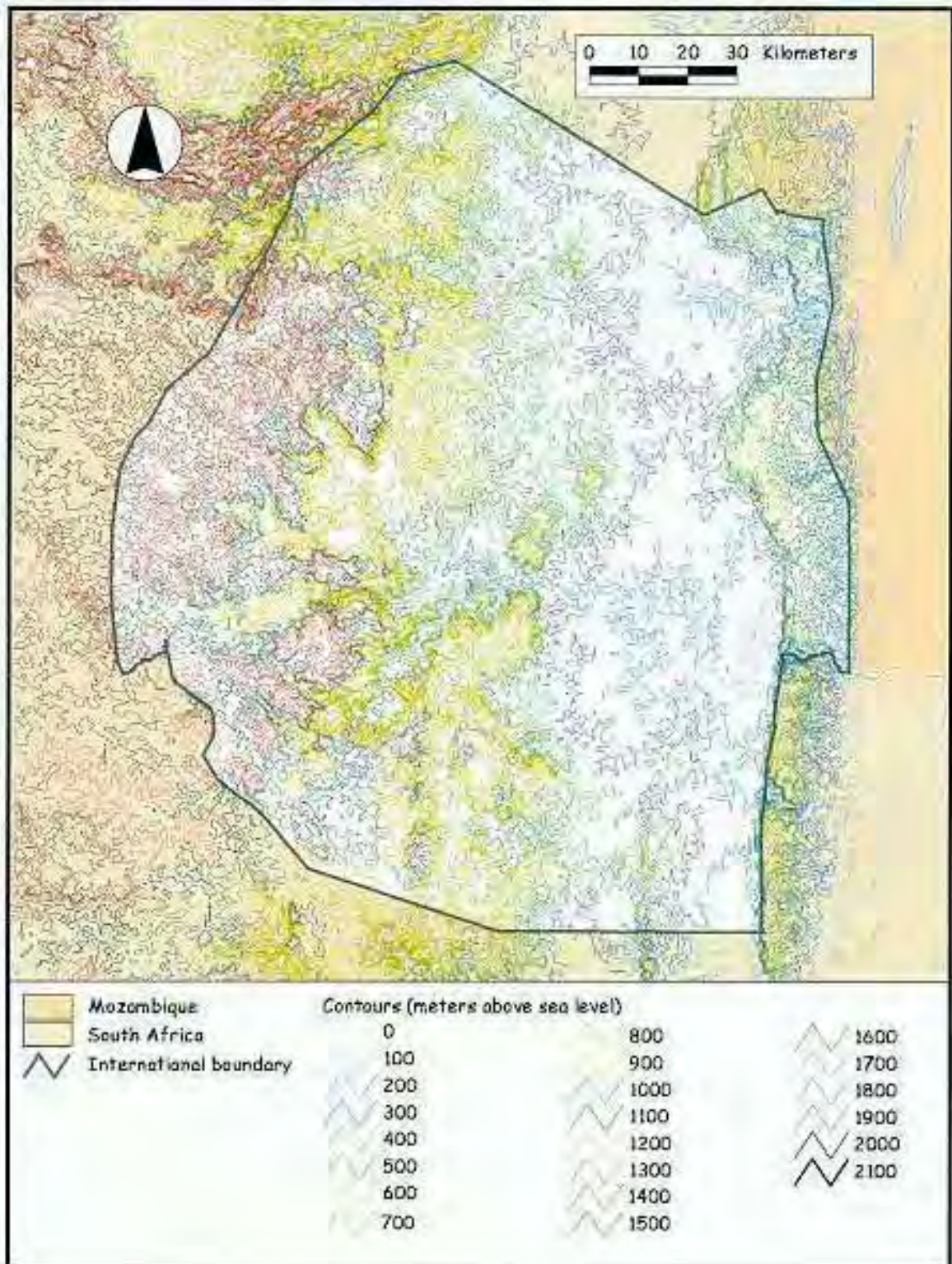


Figure 3.40: Contours

Chapter Four: Discussion

"Our creations contain more than we design in them and their value and importance increase as we explore and expose their properties" (Petch,1994:212).

4.1 Introduction

In this chapter an appraisal of the production and utility of digital atlases in Africa, will be carried out. The style of the questionnaire sent to the producers of these atlases will be briefly outlined, followed by a discussion of the answers received. The appraisal will be presented under a series of headings which reflect the main themes established in the questionnaire. The problems experienced during the production of the *Population-Environment Atlas of Swaziland* will be used to support the appraisal.

4.2 The Questionnaire

A questionnaire was sent via e-mail to the producers of *Environmental Potential Atlases (ENPAT)* (Van Viegen et.al.,1998), the *Spatial Characterization Tool* (Corbett, et.al.,1997), the *Digital National Atlas of Tanzania* (Shand,1997) and the *Population Atlas of Kenya* (Fox,1995). The questionnaire was carried out over the telephone for the producer of the *Tourism Potential Atlas of Swaziland* (Van Riet,1998).

The questionnaire consisted of twenty six open ended questions, divided into four sections. Section One attempted to establish the reasons for atlas production and the means by which work was initiated. Section Two aimed to determine the amount of work involved and any problems experienced during the production process. Section Three endeavored to establish how marketable the respective atlases were. The final section sought to gain insight into the producers opinions on the potential utility of digital atlases in Africa. (See Appendix A for the complete questionnaire).

4.3 Replies received from the producers

4.3.1 Tourism Potential Atlas of Swaziland (Van Riet,1998)

The *Tourism Potential Atlas of Swaziland* (Van Riet,1998) was commissioned by Tibiyo Taka Ngwane "as part of plans to expand the tourist industry" (Stadler,1998(c):14). The project was aimed

at classifying the country into low, medium or high potential tourism development areas. Areas were indexed according to their scenic value. Over grazed areas for example, were given a low rating whilst mountainous areas were given a high one (Van Riet,1998:pers.comm.).

No digital data was available for the country and most data relating to tourism had to be captured from scratch using PC ARC/INFO (Stadler,1998(c)). This exercise was a costly one (Van Riet,1998:pers.comm.). Although the Food and Agricultural Organization (FAO) stationed in Swaziland did provide some of the data required, none of it could be obtained digitally. With few maps to choose from, all hard copy maps available were digitized at scales of 1:250 000 and bigger. River data was extracted from the Surface Water Resources of South Africa (Water Research Commission (1997) and land cover was determined through SPOT satellite imagery. The cadastral cover for the country available from the Surveyor General's Office was purchased. Ultimately it was of little use to the project (Van Riet,1998:pers.comm.). Data captured included land use, land owners, vegetation, river catchment areas, actual and potential conservation areas and population distribution.

The project leaders indexed the layers of information for tourism potential, using their personal knowledge of the study area and by making site visits. By overlaying the maps, an overall ranking for each area was obtained (Stadler,1998(c)). ESRI's ArcView with Spatial Analyst and 3D analyst extensions was used to complete the atlas. The end result is a map indicating three zones in which the government are advised to concentrate their efforts.

The atlas has been presented to the Swazi Government accompanied by a version of ArcView 1.0. Due to the lack of GIS specialists working in the Kingdom, however, continued future use of the atlas is thought to be unlikely (Van Riet,1998:pers.comm.).

4.3.2 ENPAT (Van Viegen et.al.,1998)

The Department of Environmental Affairs and Tourism were unable to answer the questionnaire sent to them due to time constraints. A brief background to the work which had been done on the latest version of *ENPAT* (DET,1998) was however given and one of the producers sent the latest user manual in the

hope that it would provide any additional background information required. The manual held enough information to answer several queries about the product.

ENPAT (DET,1998) was born out of a recognised need for an environmental database by the Department of Environmental Affairs and Tourism in South Africa. The Department were frequently asked to contribute to development concerns where environmental input was expected (DET,1998:Chapter 2). The producers of the atlas note that during the process of formulating reports for proposed development projects, it was found that "large amounts of geographically related environmental data existed, but that it was widely disseminated between many different organizations, and captured on a variety of media in an even greater variety of formats which were not always compatible" (DET,1998:Chapter 2). Gaining access to the information was not easy due to the general "'closed shop' attitude" which mean that "it could take literally months to gain access to or acquire, certain information" (DET,1998:chapter 2). The development of a single database available to interested parties outside the Department as well as within was seen as a solution to the problem. It was decided that *ENPAT* (DET,1998) would be available at a minimum cost to any interested party.

The producers of *ENPAT* (Van Viegen et.al.,1998) see information as the key to successful management of the environment. There is no doubt that the development of their database has provided a broad spectrum of users including planners, environmental groups, developers and any member of the public with valuable environmental information (DET,1998:Chapter 1). The new *ENPAT* (DET,1998) release became available to the general public in the first week of September 1998 at a cost of R200. Acquiring the CD-ROMS and the accompanying user manual involves the simple process of filling out an order form and supplying a fax number and a postal address. The new release consists of a series of individual atlases at a national, provincial and metropolitan level. The following atlases are provided: Mpumalanga, North West Province, Northern Province and Gauteng. The Metropolitan Atlases available include Bloemfontein/Botshabelo, Cape Town, Port Elizabeth and Durban Functional Region (DFR). Each atlas consists of maps showing features such as geology, land-use, vegetation, and cadastral information amongst others (Fraser,1998:pers.comm.). Included in the package is an environmental sensitivity map for Northern Province, Mpumalanga and North West Province.

ENPAT (DET,1998) is supplied with a Viewer which is compatible with Windows '95. The Viewer allows the user to look at the maps without having to buy the ArcView software. For those users who already have ArcView, the shapefiles on the CD-ROM can be accessed with ease. The maps can be exported as bitmaps for use in presentation software such as Power Point, if so desired.

4.3.3 Digital National Atlas of Tanzania (Shand,1997)

Having built up a departmental link with the University of Dar es Salaam in Tanzania over a period of ten years Mike Shand, a senior cartographer at the University of Glasgow in Scotland, began to develop a keen interest in the country. His *Digital National Atlas of Tanzania* (Shand,1997) grew out of a "desire to create up-to-date digital data and atlas sheets of Tanzania as a means of contributing to the development of the country" (Shand,1998:pers.comm.). The intended use of the atlas at the start of production, was as a general national resource for teaching, administrators, government officials and research (Shand,1998:pers.comm.).

A formal proposal to produce the atlas was submitted to the Survey and Mapping Division in the Ministry of Lands and Settlements Development in Dar es Salaam, Tanzania. Permission to produce the atlas was granted. As there was no digital data available for the country at the start of the project, all spatial data was acquired through manual digitizing from hard copy maps. Problems with data accessibility were not experienced.

The producer of the *Digital National Atlas of Tanzania* (Shand,1997) notes that during the production process he became "well aware of the problems of finding reliable up-to-date cartographic reference material" (Shand,1997:pers.comm.). A 1:250 000 topographic map for the country was relied upon for data capture as well as maps at 1:3 000 000 scale from the 1976 National Atlas. It was decided by the Survey and Mapping Division and by the producer of the atlas, that all details would be digitized from the 1:2 000 000 map with no generalization, for future hard copy reproductions. The four map titles chosen for the atlas pilot project were decided upon according to the most up-to-date data available.

No major problems were experienced during the production of the *Digital National Atlas of Tanzania*

(Shand,1997) due a great deal of pre-digitising planning and testing which "proved invaluable in deciding the order and structure required for the data capture process" (Shand,1998:pers.comm.). The atlas was produced in-house at the University of Glasgow in Scotland as part of a Master's degree. A cartographer by profession, the producer taught himself to use the hardware and software required to create the atlas. The atlas has been developed using a 486PC and Calcomp 9100 large format digitizer. The raster data capture was carried out using an Epson GT-6500 flat bed colour scanner (A4). MapData was used to digitize and edit data. This software allows the operator to assign each map element a unique feature code, enabling the user to access the elements as separate map layers at a later stage. The base data can be saved in an ASCII format and opened as HPGL or ARC/INFO ungenerate. In this converted format the files can be viewed using a wider range of software packages. Shand notes that he "felt it important that the base map was digitized in a flexible file format to allow cross-platform access to the digital data at a later stage" (Shand,1997:pers.comm.). Converting the MapData files into HPGL plot format allowed the maps to be imported into CorelDRAW (PC based) for map design and symbol specification. Final page layout was carried out using and Adobe Pagemaker (Shand,1997:pers.comm.).

No funding was received for the atlas of Tanzania. Having made a formal proposal to produce the atlas and to train staff, the joint ATLAS2000 Proposal with the Tanzanian Survey & Mapping Division was still in limbo in June 1998 "for the usual reasons - lack of funding" (Shand,1998:pers.comm.). According to Shand, the Tanzanian government has been pouring all funds into reversing the devastation to road, rail, farms and housing caused by El Nino related storms. Despite the lack of funding, data capture and generation is being continued; probably through a personal desire to witness the realisation of the project.

In an effort to make the atlas user friendly, the producer included statistical data in tabular form to complement the map content. The *National Digital Atlas of Tanzania* (Shand,1997) is not for sale. A screen resolution version is however available on the Internet at the following address: <http://mshand.geog.gla.uk/ATLAS%20OF%20TANZANIA/atlas.htm>

4.3.4 The Population Atlas of Kenya (Fox,1995)

The *Population Atlas of Kenya* (Fox,1995) is the result of work which has grown out of personal

research. Funding for the capture of the administrative boundaries was obtained from the Human Sciences Research Council (HSRC). As work on the atlas was in the main self-funded, however, no permission for its production was sought. All data was captured from hard copy maps. There did not appear to be any significant problems experienced in accessing data for the atlas, although the hard copy maps were at times "difficult to locate" (Fox,1998:pers.comm.). The intended use for the atlas at the start of production, was to provide an electronic database to educational institutions and research communities.

The *Population Atlas of Kenya* (Fox,1995) was produced in-house at the Department of Geography, Rhodes University in Grahamstown, South Africa. All digital data was captured by the producer and two other individuals. Each person was apparently self taught from manuals with informal advice being sought where available (Fox,1998:pers.comm.). Financial and manpower limitations dictated the scale of maps from which data was captured for the atlas. 1:1 000 000 scale cadastral sheets and 1:3 000 000 scale agro-climatic sheets were used. The level of detail included was decided upon through the intuition of the producer. DOS, PC ARC/INFO and ArcView versions 1, 2 and 3 were used with 386, 486 and Pentium PCs. Few unanticipated problems appear to have been experienced during the production process.

To make the end product as user-friendly as possible a considerable amount of time was spent by the producer of the atlas, making annotations and labels for the various covers. At a cost of US\$160, 25 people have bought the atlas.

4.3.5 Spatial Characterization Tool (Corbett et.al.,1997)

The producers of the *Spatial Characterization Tool* (SCT) (Corbett et.al.,1997) are part of the Blackland Research Centre at Texas A&M University in the USA. Although no response was received from the producers, the manual accompanying the CD-ROMs held a fair amount of information with regards to the main objectives of the project.

The producers of the *SCT* (Corbett et.al.,1997) see it as an archive to close data gaps and to improve

understanding and research with regards to human-environment interaction. More specifically it was "designed to provide scientists and other decision-makers with a mechanism to easily access environmental information for characterizing target areas" (Corbett et.al.,1997:chapter 1). Although a small mention is made about data availability varying from one place to the next, very little is said about the accessibility of data used. The *Spatial Characterization Tool* (Corbett,et.al.,1997) has however clearly resulted from intensive data collection from a variety of sources. The author describes the *SCT* as "a synthesizing tool which draws from a plethora of international efforts at database construction" (Corbett, et.al.,1997:chapter 1). The climatic data was apparently collected from individual scientists and institutions who had been attempting to organize meteorological data. Data pertaining to soils, socioeconomic information, population and land use were attained from other international organizations. There does not appear to be any specific mention of African institutions playing a role in the data collection and compilation. If there were difficulties in accessing data, it is not apparent; the result is still successful.

The *SCT* (Corbett et.al.,1997) is stored as gridded ARC/INFO surfaces and ARC/INFO vector coverages. Work has commenced on the development of a standalone PC *SCT* which can be run without the use of GIS software (Corbett,et.al:1997).

4.3.6 Eastern Africa Atlas of Coastal Resources: Kenya (UNEP,1998)

The existence of the *Eastern Africa Atlas of Coastal Resources: Kenya* (UNEP,1998), was only discovered towards the very end of this research project and as a result of this, a questionnaire was not sent to the producers. Reading the introductory pages of the atlas, it becomes clear that data collection was carried out through manual digitizing and satellite imagery interpretation. It appears that much of the raw data was collected by the Kenya Marine Fisheries Research Institute and the United Nations Environment Program (UNEP). The acknowledgments list thirty institutions or individuals from which data and information was collected for the atlas. Created out of a need to ensure future sustainable utilization of the country's coastline, the success of the data collection must surely owe itself in part to the common interest of the providers of data. The majority of the individuals' names or institutions mentioned all have strong links to the coastal environment.

4.4 An appraisal of the production of digital atlases in Africa

4.4.1 Data accessibility

Each of the producers of the various digital African atlases appears to have had very different reasons for embarking on their projects. Before receiving answers to the questionnaires which were sent to them, it was expected that their experiences with data accessibility would reflect the backgrounds they were working from. The producers of the digital atlases of Tanzania and Kenya were individuals. Their atlases grew out of personal research and it was thought that because these producers were not doing the work for government, that problems with data accessibility would be more likely. Having received the replies to the questionnaire, it has become apparent that neither applied for permission to access digital data. All data was captured from hard copy maps which on the whole were readily accessible. Most mapping departments in Africa are more than happy to sell hard copy maps available for their countries as issues such as copyright on written or printed material is well established. Unfortunately many hard copy data sources in Africa are outdated, and discretion in their use is essential to ensure a successful outcome.

It was expected that as part of the South African Government's Department of Environmental Affairs and Tourism, the producers of *ENPAT* (Van Viegnet.al.,1998) would have had the influence to access data sets which might otherwise have been difficult to obtain. Recognised as a reputable body, the department was thought to be more likely to gain access to data from non-governmental organizations, than individuals would be. These assumptions proved to be incorrect. Problems relating to data accessibility before the first release of *ENPAT* (DET,1994) were a motivating factor in its production.

The producers of the *Tourism Potential Atlas of Swaziland* (Van Riet,1998) were commissioned by the Swazi government to carry out the project. As a result of this, problems with access to data were expected to be minimal. It is necessary to keep in mind that the digital data sets held by government were and still are limited. The cadastral database developed by the Surveyor General's Office is available at a cost to anyone who requests access to it. It appears however, that some frustration was experienced in trying to secure access to existing digital data held by one of the main organizations in the country.

Due to the fact that a reply from the producers of the *SCT* (Corbett et.al.,1997) was not secured, the

problems that they may have had in terms of access to data is uncertain. As a foreign team however, it is expected that they may have been received in a positive light with data accessibility not being a problem. As members of a research station, it is also highly likely that they had access to the data sets of fellow scientists working in Africa.

Despite the expectation that acquiring data would be fairly difficult for the *Population-Environment Atlas of Swaziland*, the initial collection of statistical volumes from the Census Department in Mbabane, was fairly straightforward. Before the Census Commissioner had had any confirmation of the validity of the research, he was happy to provide the 1986 enumeration data requested. This was the latest census information available for the country with the 1997 census statistics still being processed (Mamba,1998:pers.comm.). **Table 4.1** provides a summary of the periods of data collection carried out for the *Population-Environment Atlas of Swaziland*.

1997	DATA COLLECTION
January	1) Obtained the 1986 census data in statistical volumes from the Census Commissioner of Swaziland, without any delays. 2) Unable to access 1997 census data as it was still being processed. Assured that as soon as it became available, access would be granted immediately. 3) Purchased a 1:250 000 topographic map of Swaziland (1989) at a cost of E10 (One Lilangeni = One Rand). 4) Given three 1:250 000 sepia transparencies (1986) showing population distribution, population density and the 1986 enumeration areas.
February	
March	
April	1) Thesis supervisor writes to the Census Commissioner of Swaziland to determine whether or not the proposed atlas "would be of use and interest to" (Fox,1997:pers.comm.) the Census Department.
May	1) 1:50 000 map series covering the entire country are ordered from Map Office in Johannesburg (R650).

June	1) Reply received from the Census Commissioner who affirms his interest in the project
July	
August	1) 28 out of the 32 map sheets of the 1:50 000 map series arrive from Johannesburg
September	1) The remaining 1:50 000 map sheets arrive.
October	
November	
December	<p>1) Visit to the Census Department; the 1997 census data is still unavailable.</p> <p>2) Informal interview with Petrunella Mamba (Statistics division) reveals the process of census data collection and reasons for the delay of the 1997 census data.</p> <p>3) Gerard Dlamini (Statistics division) supplies a dialine copy of the provisional 1997 enumeration areas (1:175 000). A hand written list of the new parcel id numbers is also given (see Appendix B).</p>
1998	DATA COLLECTION
January	<p>1) Informal interview with the project leader of the digital cadastral database. Problems with software precluded viewing of the product. Suggestion that the Ministry of Agriculture (MoAC) should be consulted as they were believed to be using GIS (Johnson,1998:pers.comm.).</p> <p>2) Informal interview with senior consultant in the Department of Land Use and Planning (MoAC). GIS (IDRISI) is used to produce land use maps.</p>
February	1) Fax is sent to the Senior Land Planning Officer in the Department of Land Use and Planning to request access to IDRISI files.
March	
April	

May	<p>1) DEM for Swaziland is ordered from ComputaMaps in Cape Town (R250).</p> <p>2) Letter sent to GeoInformation Africa requesting to be contacted by anyone with information on African digital atlases</p> <p>3) E-mail received granting access to IDRISI files from the Department of Land use and Planning</p>
June	<p>1) Questionnaire is sent via e-mail to the producers of the <i>Digital National Atlas of Tanzania</i> (Shand,1997), the <i>Spatial Characterization Tool</i> (Corbett, et.al.,1997) and the <i>Population Atlas of Kenya</i> (Fox,1995)</p> <p>2) IDRISI files are received successfully over e-mail after two unsuccessful attempts.</p>
July	<p>1) The British Council in Mbabane is contacted to find out more about a report in <i>Swaziland Today</i> relating to digital mapping in the country.</p> <p>2) Second informal interview with project leader of the cadastral database who was able to demonstrate the now completed project for the country.</p> <p>3) Informal interview with the project leader of the digital mapping programme for the country. Details of the programme are established.</p>
August	<p>1) Questionnaire sent via e-mail to the producers of <i>Environmental Potential Atlases</i> (Van Viegen,et.al.,1998).</p> <p>2) The producer of the <i>Tourism Potential Atlas of Swaziland</i> (Van Riet,1998) is contacted over the telephone to answer the questionnaire.</p>
September	<p>1) Reply from <i>ENPAT</i> (Van Viegen et.al.,1998) producers who are unable to answer the questionnaire.</p> <p>2) Letter sent to GeoInformation Africa is published; awaiting replies</p>
October	
November	<p>1) Questionnaire answers received from the producers of the <i>Population Atlas of Kenya</i> (Fox,1995) and the <i>Digital National Atlas of Tanzania</i> (Shand,1997)</p>
December	

Table 4.1: Summary of data collection for the *Population-Environment Atlas of Swaziland*

The initial response from the Census Commissioner, evident in the ready provision of maps and statistical volumes, was encouraging even though written approval took some time to obtain. As work on the atlas had not been commissioned by government, the reception to its proposal was uncertain. The interest expressed by the Census Commissioner was therefore very motivating. Access to the 1986 census data was given and subsequent access to the 1997 census, promised. A motivated and dedicated environment is considered to be essential to the success of a project such as the production of a digital national atlas.

Returning to the Census Department in December 1997, an informal interview with a senior member of the Statistics division revealed why the census data was still unavailable. High school children had been used to carry out the census questionnaires. Teaching the children how to administer the questionnaires depended heavily on teacher cooperation. During this time however, there was a large scale teachers strike during which the census data collection was adversely affected and the process had to be repeated (Mamba, 1998: pers. comm.). The second census took place at the beginning of 1997. By January 1998 the data was being entered into a spreadsheet with completion being expected around June or July 1998. The total population numbers for each region were obtained, but the statistics for each enumeration area were unavailable. The enumeration statistics for 1997 have been unavailable up to this point.

The 1997 enumeration areas map is being produced in Swaziland for the first time. Loxtoll, a mapping company in Johannesburg has previously been responsible for the production of the enumeration area maps for the country. A dialine copy of the provisional enumeration areas of the 1997 census was obtained. The new subdivisions of the old 1986 enumeration areas have been made more visible by producing the map at a scale of 1:175 000 (Dlamini, 1997: pers. comm.). It was indicated that the final enumeration areas map would be produced at the same scale. In the digital environment the time involved in updating these types of maps could be significantly reduced.

Digital data was obtained relatively easily from the Department of Land Use and Planning in the Ministry of Agriculture. Talking to a consultant in the department revealed that the information generated by the office tended to be rather guarded due to unfortunate experiences with data exchanges in the past, where data had been 'borrowed' and then subsequently sold. The department are now understandably careful

when granting access to their data sets. It was noted that whilst "there's no problem with non-digital data (maps & reports)...the Ministry's position on giving out digital information is less clear" (Van Waveren,1998:pers.comm.). For access to data, applications have to be made in writing to the Senior Land Planning Officer, being careful to specify exactly what data is needed and for what purpose. Very little happened for two months and then permission was suddenly granted. This occurred after an enquiry was made by a contact in Swaziland where it is entirely possible that some 'strings were pulled'.

The digital files from the Ministry of Agriculture were received over the e-mail with several user conditions attached. It was noted that the ministry had not yet formally formulated the conditions, but the basic outline amounted to the following:

- "a)You are not allowed to use the data for any purposes other than those for which permission was granted
- b)You have to clearly acknowledge the data source in your reports and any separate maps
- c)You cannot make any modifications without the Section's explicit permission" (Van Waveren,1998: pers.comm.)

The hard copy user manuals were readily acquired at a nominal fee of E20 each. Being granted access to this data was greatly appreciated as there is always a chance of being refused.

It is not possible to generalise about inaccessibility to existing digital data being a particular limitation in the production of digital atlases in Africa, as only two producers mentioned experiencing problems. These were the producers of the *Tourism Potential Atlas of Swaziland* (Van Riet,1998) and *ENPAT* (Van Viegan, et.al.,1998). It is necessary to keep in mind however that the remaining producers did not apply for access to any digital data sets, which is possibly why they did not face any significant difficulties.

The general impression after having spoken to four people who work for government in Swaziland, is that data flow between departments is poor. There appeared to be very little knowledge about what other departments were doing with regards to GIS work for example. If each department were more aware of the extent and type of data they had, data duplication could be reduced and information dissemination fostered.

In a commercial setting the amount of time spent on data collection constitutes a large proportion of the cost of a project. Spatial data for most African countries is limited and if digital data for these territories

is captured by governmental or non-governmental organizations, it is of utmost importance that access to that data is made available. Information held under lock and key is of use to a very limited number of people. If departments are nervous about providing access to data, legal guidelines for its use should be set up. Data accessibility is thought to be one of the most important factors in the successful production of digital atlases in Africa. If data is made available through cooperation between departments and organizations, the length of time required to complete digital national atlases could be drastically reduced.

There is little doubt that remotely sensed data could help fill in the gaps for many African data sets. Some areas are so vast that detailed mapping 'on the ground' would be an impossibly expensive undertaking. The only drawback to this is the cost of acquiring the images and the need for experienced personnel to interpret the results.

"The Internet, in conjunction with other technologies, presents a new way of bringing GIS applications to African countries..." (Stadler,1997(d):27). The African Data Dissemination Service (ADDS) (US Geological Survey (USGS),1998) is one site which has the ability to serve as a digital data archive for the continent. Looking at the ADDS (USGS,1998) web site briefly, numerous countries have been listed, but most have very little digital data on offer.

The ADDS (USGS) homepage outlines possible options for the viewer to choose from. These include a project overview, data holdings of the organization and an overview of the data providers. The user has the option to access data according to Geographic Area, Region/Country, Data Theme or Geospatial Search Engine. An error message indicating that the server was down or busy was received when the 'project overview' was selected. The 'data providers' were then accessed to see who the main contributors to the data service were. There were no African researchers amongst the organizations listed. The contributors include the Associates in Rural Development, Inc. (ARD) from Burlington in the USA, the General International Science and Technology Institute, the Office of Arid Land Studies (OALS) at the University of Arizona, the National Aeronautics and Space Administration (NASA), the National Oceanic and Atmospheric Administration (NOAA) with country information (area, capital, official languages, currency and continent maps) obtained from the CIA WorldFact Book. The ADDS

(USGS,1998) server data holdings allow the viewing and download of data for the whole African continent, regions of the African continent or individual countries.

By choosing to look at the ARD site, one has the option to search their geographic information services and technologies. A list of current projects is given; all of which are being carried out in third world countries. One of the projects reported on is an 'Assessment of Country-wide GIS Potential in Botswana'. The government of Botswana is reported to be swamped by a proliferation of GIS systems and databases which have been used in a wide variety of applications. Standards for database development have not been common to all organizations which has resulted in a lack of coordination and costly duplication of data capture (ARD,1998). The Botswanan government has sponsored ARD to look at the country's GIS requirements and capabilities in seventy government ministries, departments and private sector organizations over a one year period. Returning to the ADDS (USGS,1998) homepage, digital data was searched for on several countries. Starting with Botswana, the country flag, country specific information and a list of available digital data for the country was displayed. Under the 'Satellite/Image Data', a Normalized Difference Vegetation Index (NDVI) was available for the country. 'Digital Map Data' provided an administrative boundaries map or a reference map which could be viewed or downloaded. There was no mention of the project which the Botswanan government has commissioned ARD to carry out.

With knowledge of the existing digital atlases of Kenya and Tanzania, it was decided that the sites for these two countries would be opened. The NDVI was available for both as were administration and reference maps. Kenya had an additional rain stations map accompanied by a statement which noted that the cover should not be used for navigation or for the production of maps needing high geodetic accuracy (USGS,1998). There was, however, no mention of the existence of digital atlases for either country.

Looking at the digital data available for Swaziland, an attempt was made to access the NDVI. An error message was received indicating that the requested address could not be accessed. The digital map data includes the usual reference map available for the country, displaying the towns, main roads and rivers.

The key on the administrative boundaries map refers to a 'level 2 boundary'. This boundary represents the districts. It was felt that more information should be provided to the user. There are considerable footnotes relating to the ARC/INFO polygon covers. The administrative boundaries were apparently captured at 1:100 000 scale as part of a Famine Early Warning System (FEWS) and ARD project and can be ordered over the Internet. The purpose of the map is also given. It is hoped to be used in conjunction with other data layers, to show the spatial distribution of the international boundary and lastly is to be used in modelling and demonstration projects. In the realm of writing attached, it is noted that if the data is used, USAID, FEWS, EDC, the International Program and the US Geological Survey should be acknowledged. A disclaimer has been added to the data and a note to say that "this data set contains data that has copyright protection and is not for general (public) distribution" (USGS,1998). Firstly the scale of map from which the data has been captured, is not that detailed and as a result is possibly not worth ordering; secondly, access is denied if one is part of the general public.

In Africa there is little doubt that the Internet could help promote data dissemination and a site like ADDS (USGS,1998) could be used to report on and store data sets from current GIS projects for individual countries. E-mail addresses of people involved in particular projects could be made available should another country want advice on a similar project. More detailed data sets could be made accessible through a joint effort of governmental and non-governmental organizations. It is necessary to bear in mind however that in Africa, there are 700 million people and less than one percent have access to the Internet (Stadler,1997(d)).

Data sets are becoming increasingly available at a cost, from private organizations. The Human Sciences Research Council (HSRC) has produced a data set described as "an atlas that aims to show the service needs of South Africa's nine provinces" (Reporter,1998(b):12). The report states that the HSRC is encouraging access to the information which has been generated. The cost of the digital data is noted as being between R10 000 to R15 000. Although one can accept the cost of data capture and the need for organisations to recoup costs, payment for Data sets such as these may be beyond some budgets and should be modified for particular concerns.

In May 1998, a letter was sent to the editor of GeoInformation Africa, asking if she knew of any other African digital atlases being produced. The letter was placed in the mailbag section of Issue 7 (September 1998). Unfortunately, no feedback has been received. The flow of information between GIS users in Africa needs to be fostered. Although there has not been much time to receive input, it would have been of great use to gain the opinions of more African digital atlas producers.

4.4.2 Data source issues

The producer of the *Tourism Potential Atlas of Swaziland* (Van Riet, 1998) appeared to find the choice of maps to work from, limited. As a result of this, a wide variety of data sources at varying scales were relied upon. Retrieval of data from such diverse sources requires a broad knowledge base; a requirement which can be difficult to secure in the African context where in most cases budgets are limited.

It would seem that the lack of digital data captured for African countries, has meant that a measure of reliance has been placed on existing hard copy maps for data capture. The producers of the *Digital National Atlas of Tanzania* (Shand, 1997), the *Population Atlas of Kenya* (Fox, 1995) and the *Tourism Potential Atlas of Swaziland* (Van Riet, 1998) all indicated that they had manually digitized hard copy maps in order to capture data. As has already been discussed in Chapter Two, a lack of up-to-date paper maps is a problem in many African countries at present. The accuracy and level of completeness of available base maps has the ability to prevent many African countries from embarking on and producing worthwhile digital mapping products. During the production of the *Population-Environment Atlas of Swaziland*, several problems regarding map standards were met.

The first problem related to the way in which the map elements had been displayed. At the start of the project, the maps acquired included a topographic map of Swaziland (1989). This map provides the viewer with a generalized overview of most features of the country; one can immediately see the major road network, generalized land use and towns for example. An attempt was made to digitize the district boundaries from this map. The boundary line had been represented as a series of crosses which were difficult to follow for digitizing. The district boundaries however are merely outlined for orientation purposes; they were not suitable for accurate data capture. Likewise, digitizing the boundaries from the

dialine copies, was inappropriate. Although the boundary representation was clearer in both maps, it was hand drawn and the boundary ran out in places along the river on the population distribution map. On the population density map, density circles obliterated the boundary line. For greater accuracy, it was necessary to digitize the district boundaries from the 1:50 000 map series. The 1:50 000 map series for Swaziland was produced in 1991. Although seven years out of date, this map series is probably more recent than those available for many African countries. This map series had to be ordered at a cost of R20 each and 31 sheets were required, making the total cost R620. This is an additional cost which producers of national digital atlases would need to add to their expense sheets.

The enumeration areas map had been draughted at 1:250 000 scale; this data does not exist at a larger scale. Some of the lines on this map were particularly difficult to make out. The locational accuracy of the map was questioned; it did not fit within the international boundary when the two were overlaid. The geodetic accuracy of the enumeration area cover is uncertain.

If the base maps of African territories were up-to-date, the cost of hardware (digitizing tablets or scanners) still may preclude those African countries who wish to embark on digital mapping projects from doing so. Assuming that the base maps are of an acceptable quality, digitizing appears to be the more affordable option

4.4.3 Data capture; Digitizing

Although it is not particularly difficult to learn, poor digitizing habits and human error can introduce inaccuracies above and beyond those already inherent in source base maps. Many of the errors identified during the digitizing of the *Population-Environment Atlas of Swaziland*, were entirely human related.

Digitizing from the enumeration area map took place over three weeks and in this time, the map was removed from the digitizing tablet once, to minimize damage. The digitizing was carried out as quickly as possible, to avoid the effects of stretching or warping of the paper. The measure of error which could have crept in over this two week period could however still have been significant.

With the numerous lines on the enumeration areas map, digitizing had to be carried out methodically to make sure that lines were not omitted by mistake. Lines which had been digitized were highlighted with a yellow marker to distinguish them from those which still needed to be captured. The difficulty of seeing some of the lines on the enumeration area map for example resulted in the digitizing of parcel boundary lines which were in fact roads. Some boundaries were omitted altogether. This kind of error was only noticed at a later stage when covers had to be joined and resulted in a lengthy process of checking and correcting. This was an extremely time consuming process which in a commercial setting would be costly.

Maintaining some sort of structure to the data capture process is very important. The producer of the *Digital National Atlas of Tanzania* (Shand, 1997) carried out extensive pre-digitizing planning to avoid any major problems occurring during the data capture process.

It was found that many errors can in fact be avoided with experience. It is impossible to learn how to troubleshoot without being forced to work through problems time and again. Errors can creep into the database at different stages of production. In the production of the *Population-Environment Atlas of Swaziland*, entering incorrect enumeration id numbers for example made for confusing results when the cover was viewed in ArcView 3.0. Keeping a journal of the production process made it relatively easy to back track and rethink where a wrong step may have been taken. If there are several people assigned to a data capture project, it is suggested that each person completes their own data capture section. If anyone else had tried to follow the thought processes recorded in the journal during the production of the *Population-Environment Atlas of Swaziland*, the troubleshooting process would have taken that much longer. It is felt that none of the requirements related to successful digitizing are out of reach of African countries.

4.4.4 Format

Standardization of digital data formats is one area in which African countries are going to need to focus their attention if data flow is going to be fostered and unnecessary costs of recapturing data or converting data are to be avoided. One of the reasons for the development of *ENPAT* (DET, 1998) was to avoid the problem of incompatible data sets. The project leader of the cadastral database in Swaziland, made

particular mention of the fact that converting the database from UNIGIS into a more conventional format was one of their future priorities (Johnson,1998:pers.comm.). The format that the database is in now is limited to those who are able to convert it into ARC/INFO or use it as it is. The project leader of the digital mapping project in Mbabane noted that the data they were capturing was going to be made available in four different formats to make it accessible to as wide a user base as possible. Ultimately it is hoped that all digital data which has been captured for the country will be held in a national database (Simelane,1998:pers.comm.). Noting that there was not much choice with regards to the scale or type of maps available for the *Tourism Potential Atlas of Swaziland* (Van Riet,1998), several digital data sources were tapped. Capturing data from such a variety of sources is no doubt costly, but now that it is in a useable format, it should be incorporated straight into the developing national database.

Problems with compatibility were experienced with the land use covers acquired from the Ministry of Agriculture. They arrived in an old version of IDRISI format and some professional help in the form of Dr. Tony Palmer (from the Albany Museum, Grahamstown) had to be sought. It was only after a process of trial and error that the files could be opened in IDRISI for Windows. The images then had to be imported into ArcView 3.0. Opening the files was again time consuming, as the process was unfamiliar. It is imperative that data capture is carried out in a format accessible to the majority of users.

The *Tourism Potential Atlas of Swaziland* (Van Riet,1998), the *Population Atlas of Kenya* (Fox,1995), *ENPAT* (DET,1998), the *SCT* (Corbett,et.al.,1997) and the *Eastern Africa Atlas of Coastal Resources:Kenya* (UNEP) have all been developed on ARC/INFO software and in theory should therefore be compatible. Having opened the *SCT* (Corbett,et.al.,1997) with ease, one of the coverages from the *Population-Environment Atlas of Swaziland* was overlaid. The international boundary of the *SCT* (Corbett,et.al.,1997) is significantly more generalised, but the covers overlaid without a problem. Coverages from the atlas however could not be overlain with those from *ENPAT* (DET,1998). *The Environmental Potential Atlases* (DET,1998) coverages have been projected into albers whilst the coverages in the *Population-Environmental Atlas of Swaziland* are unprojected. These problems can be overcome relatively easily without having to convert data. Having access to a wider variety of data sets increases the possible utility of a product such as a digital national atlas. The

more data layers which can be used in conjunction with each other, the more composite information will become available.

4.4.5 Software

The main problems experienced with the software during the production of the *Population-Environment Atlas of Swaziland* were as a result of inexperience; most of the work involved discovery by trial and error. In several cases, covers were noticeably mismatched when they were overlaid. Small errors which were not noticed until after the covers had been transformed for example, meant returning to the original cover, editing it and following through the process again. These problems were, more often than not, related to mistakes which had been made in the tic files of the separate covers. Forgetting to alter fuzzy tolerances resulted in the over-generalisation of lines where nodes had been snapped together. Realising the mistake again meant returning to the original cover, setting the necessary tolerances and starting over. Correcting the errors was time consuming, but it is accepted that the teething process can be lengthy; this is part and parcel of familiarising oneself with the product. Problems such as these however are easily recognisable after dealing with them several times, so whilst the initial problem solving could be time consuming and costly, this may decrease as experience is gained. The likelihood of experiencing similar problems by other producers is quite high. Due to the size of Swaziland, achieving a relatively detailed and accurate digital national database should not pose too many problems for the country. For larger African countries the process could well turn out to be too costly.

Attempting to open the IDRISI files in IDRISI for Windows proved to be problematic. The main problem was that "most GIS systems, including IDRISI for Windows, don't like the SA grid because the lowest x,y values are always in the upper right corner of the map" (Van Waveren, 1998: pers. comm.). Developed in the Northern hemisphere, systems like IDRISI recognise the coordinate systems relevant to that area.

Some errors such as sliver polygons, which had been created in PC ARC/INFO, were only visible in ArcView 3.0. This was extremely frustrating as the cover had to be reopened in PC ARC/INFO to make the corrections. This increased the amount of time required for data capture. Software is becoming more

user-friendly all the time, the problem with this is that most African institutions may have the funds to buy one version of software, but will in all likelihood be unable to afford subsequent upgrades.

That software should be available in the language of the user has been a common thread in the literature. The experience gained from the production of the *Population-Environment Atlas* has supported this to a certain extent. Throughout the data capture process for this atlas, the ESRI manuals accompanying the PC ARC/INFO software were heavily relied upon. In many cases the explanations were felt to be too brief. With English as a mother tongue, an advantage exists over someone who is trying to decipher these manuals with English as a second language. There is no doubt that manuals need to be translated into the first language of the operator. The atlas produced this year by the Human Sciences Research Council (HSRC), aimed at service provision in the provinces of South Africa, comes complete with a multi-lingual user interface. The maps can be read in English, Zulu, Xhosa, Northern Sotho, German and French (Stadler, 1998). This will greatly improve the value of the product with increased understanding and appropriate usage guaranteed.

The cost of software may be one area which limits the adoption of digital mapping exercises or the production of digital national atlases in Africa. Using the GIS equipment available at Rhodes University, access to PC ARC/INFO, ArcView 3.0 and IDRISI for windows software was readily available. The producers of the *Digital National Atlas of Tanzania* (Shand, 1997) and the *Population Atlas of Kenya* (Fox, 1995) also both had access to the facilities of their respective universities. The fact that the expense of buying equipment was not experienced, is significant. If the projects were not successful, money had not been wasted; the equipment would still be used by the respective learning institutions. One needs to take into account the fact that the purchase of software and hardware for digital mapping is costly. For organizations which have failed to see a digital mapping project through to its logical conclusion, the equipment is likely to be left unused.

Having made a decision to buy the necessary hardware and software, African countries need to be sure that the products will be useful not only to a select few, but to a broader base of people. The *Eastern Africa Atlas of Coastal resources: Kenya* (UNEP, 1998) is noted to currently be available to

administrative institutions, research and academic interests, but "its electronic format will keep it beyond the reach of a large number of potential users" (UNEP,1998:3). To get around this problem in the meantime, the atlas has been distributed as a series of hard copy maps with an accompanying book.

Software packages such as PC ARC/INFO and IDRISI have been highlighted as being too expensive to adopt by African countries (Verheust,1998:pers.comm.). In a conference held at Rhodes University in July 1998, Mr Verheust, a fisheries and Data Management Officer in Zimbabwe, gave a talk on the use of GIS in the Aquatic Resource Management Program for Local Communities (ALCOM). He noted that they use the simplest system possible. For digitizing their data, WINDISP is used. This is a free program which has been developed by FAO. It is a raster mapping package with its only major disadvantage being a colour range limited to 250 classes. Map Viewer is used with custom written software. The solution for by-passing expensive software may have been found by this organization, but it still appears to be lead by a foreign team. Local people need to be trained in software design to ensure their needs are met now and in the future.

4.4.6 Hardware

The *Population-Environment Atlas of Swaziland* was produced on a 486 PC with 32 meg of RAM and latterly a Pentium PC with 94 meg of RAM. The difference in speed during the use of commands such as CLEAN when using the Pentium was marked. To reduce production times, the highest powered PC affordable should be used. Owing to the computer crashes which were experienced whilst using the 486 PC during the production of the *Population-Environment Atlas of Swaziland*, it is suggested that only computers of this capacity or above should be considered for use in atlas production. The frustration factor with regards to computing speed and reliability may be too high if lower capacity computers are used. It is necessary to mention however that the computers which were being used to produce the *Population-Environment Atlas of Swaziland* were open for use to all postgraduates and staff (+ 20 people) as well as undergraduates during GIS coursework (+/- 40 people). The usage was therefore relatively high with hard drive space being taken up by other people's work; a full hard disk was the

cause of one of the computer crashes. If work is strictly archived and hard disk space is maintained, these problems may not be experienced.

As with software, the cost of hardware could be a limiting factor in the African situation. Woods (1993) suggests that developing countries have the capacity to assemble a few parts of the hardware required in IT, which would reduce costs. Another option is to consider the second hand market for purchasing hardware. If maintained properly however, good quality equipment could last a considerable amount of time. In the Surveyor General's Office in Mbabane, the photogrammetry stations that have been used for 15 years have simply been incorporated into the more modern set up by linking them to computers instead of the usual plane tables.

The hardware required to produce the *Population-Environment Atlas of Swaziland*, and the *Population Atlas of Kenya* (Fox, 1995) essentially amounted to a computer and a digitizing table. For the *Population-Environment Atlas of Swaziland*, a Summagraphics Summagrid IV digitizer and a Houston Instrument digitizer were used.

4.4.7 Liveware; training

Learning to digitize data from hard copy maps, is not difficult. Once the steps have been learnt and repeated, many of them become habit. It is suggested, however, that a geographic background of some sort is an essential. Having completed a geography honours course in GIS with a very small practical component but a considerable theoretical component, work on the *Population-Environment Atlas of Swaziland* was the first major data capture exercise embarked upon. As a geography student, spatial awareness was understood and provided an invaluable understanding of the GIS environment. The opportunity to 'practice' before data capture for the atlas began was important. A digitizing job over a period of two months was commissioned, providing invaluable experience.

African institutions looking to employ people for data capture cannot rely on the trainees to teach

themselves the basics. As a cartographer, the producer of the *Digital National Atlas of Tanzania* (Shand,1997) clearly had the necessary training in spatial applications which is a great advantage in the learning and use of Geographic Information Systems. Having a solid understanding of map work and a spatial awareness is a necessary starting place in the training of people to use GIS. Three people were involved in the creation of the *Population Atlas of Kenya* (Fox,1995); all geographers by training. A lack of training limits the utility of digital atlases. The *Tourism Potential Atlas of Swaziland* (Van Riet,1998) is unlikely to be used in the future due to a lack of skilled manpower in the kingdom.

Learning from mistakes and taking time over problem solving is a luxury which may not be afforded in the business setting. Even with experts at hand to point people in the right direction when they hit a problem, the most valuable lessons are often learnt when one has to sit and work it through for oneself. Training courses for people need to be thought out very carefully, taking into account that 'spoonfeeding' is often not the best way of learning. The time needed and the costs involved may be a limiting factor to digital atlas production in Africa.

4.4.8 Funding

The Census Commissioner for Swaziland indicated that his department had the computers necessary for digital mapping, but did not have the funding to train staff. Realising that there would be no funding available from government to produce the *Population-Environment Atlas of Swaziland*, it became a personal venture, relying on other sources for some of the money needed. Having access to the necessary hardware and software meant that operation costs were not as high as they could be for such a venture. The only payment necessary was for several trips to Swaziland, the printing of maps and the writing of the atlas onto CD-ROM. A lack of funding certainly did not hinder production in this case, but on a larger scale project where field workers need to be paid and data capture is carried out to a greater extent, it is easy to see how a drought in funds could bring a project to a standstill.

In the case of the *Digital National Atlas of Tanzania* (Shand,1997) where funding has not been

forthcoming, the producer has continued data capture. The likelihood of people working voluntarily on a project like this is small, unless personal interest is great enough. In a recent communication dated November 1998, it was noted that funds had still not been made available. It is essential therefore that adequate funds are secured before work begins.

Where funding can be secured, for example in cases such as the *Tourism Potential Atlas of Swaziland* (Van Riet, 1998) which was commissioned, a budget for the production can be worked out. Knowing that there are adequate funds to complete a project, is important. The possibility of running out of money could have a significant effect on the level of motivation of the team working on the project. Whilst the UK based Department for International Development for Swaziland funded the initial purchase of computers and training for the digital mapping project in the country, the project leader noted that he was hoping that funds promised by the Japanese government would come through by September 1998. If these funds did not arrive one might be tempted to ask what happens to the project; surely it cannot be left half completed. One would imagine that the DFID might step in, but one cannot rely on this.

Less financial aid is reaching African countries these days. The South African government is making a concerted effort to encourage people to rely on themselves rather than outside aid. Local Economic Development (LED) encourages community level reliance. If this could be fostered at departmental level in government, and money could be raised within a country to pay for digital mapping projects for example, perhaps there would be more of a case to be made in favour of African countries utilizing this technology.

4.4.9 Subjectivity; deciding what to include

When the production of digital atlases is undertaken by individuals who are not adhering to production guidelines, personal choices play a significant role in the presentation of the end product. It has already been stated that the undertaking of a digital project such as a digital atlas, should take into account the needs of the end user. In the case of the Tanzanian, Kenyan and Swaziland atlases, possible end users were identified, but their exact needs were not determined. As a result of this factors such as the levels of detail captured and features included to improve user-friendliness, have been decided upon by each

producer. The possible result of this, is a group of countries with national digital atlases captured from a variety of scales with varying levels of accuracy and usability. Production of digital atlases in this fashion may serve as a useful platform from which to start a national database, but additional data capture may need to take place to generate greater detail depending on the needs of the user.

In cases where different parties have captured digital data for the same country, frustration can arise. Using the 1:250 000 topographical map as their base map for example, the Department of Land Use and Planning have produced seven covers for Swaziland. Overlaying a cover from the *Population-Environment Atlas of Swaziland* captured from the 1:50 000 map series, the boundaries do not quite meet. This could affect the results of any queries carried out using covers from the two different data sets.

It is suggested that standard guidelines for the production of digital atlases could be set up to try and ensure that levels of detail are more or less uniform. If work was being carried out on the border of Tanzania and Kenya for example, and the two available digital atlases were used, differences in the level of available data could be quite frustrating.

Each person's opinion of what makes something easier to comprehend, will differ. When asked what measures had been taken to make the atlas particularly user-friendly, the variety of answers reflected personal opinion. The producer of the *Population Atlas of Kenya* (Fox, 1995) noted that annotations and labels for the various covers had taken up much of his time in the effort to make his atlas easier to work with. The producer of the *Digital National Atlas of Tanzania* (Shand, 1997) indicated that statistical data fed into tabular format was included to complement map content. The producers of the *Eastern Africa Atlas of Coastal Resources* (UNEP, 1998) have made an effort to present the atlas in a user friendly format, realising that the majority of the interested parties do not have access to the necessary computing equipment to work with it. As a result of this, the maps have been distributed as hard copy map sheets; a format which is familiar to most, until hardware and software becomes more widely available.

The analytical capabilities of the *SCT* (Corbett et.al., 1997) are outlined in the accompanying manual as

site (point) characterization (climate, population density etc.), zone mapping, zone (area) characterization, transect generation and dynamic plot (Climatic change over a year). The producers have noted that whilst many organizations have attempted to develop environmental data sets, the user had to be a GIS specialist to access it. The modified Graphical User Interface (GUI) in product is aimed at the non-specialist as well. The ease with which these data sets are opened from CD-ROM, indicate how user friendly they are.

The producers of *ENPAT* (Van Viegen et.al.,1998) as members of a significantly larger team have provided their atlas in a carefully designed package. They actively encourage feedback from their user base, but updating of their atlases will be limited to as few editions as possible due to cost, unless "changes in information or the availability of newer or more accurate data sets" (DET,1998:chapter 8) arise. The Viewer included in the package is evidence of the effort which has been made to make the atlas as usable as possible. The amount of detail included in digital atlases and the number of features added to improve usability is of course directly affected by available funding.

Other differences which may cause frustration to the users, are discrepancies in the cost of atlases and data sets. The *Tourism Potential Atlas of Swaziland* (Van Riet,1998) as mentioned previously, was a commissioned work and belongs to Tibiyo of Swaziland. General access to the atlas has not yet been determined. The *SCT* (Corbett,et.al.,1997) is available as a series of CD-ROMS with a manual at a cost of US\$40. The *National Digital Atlas of Tanzania* (Shand,1997) is not for sale. *ENPAT* (Van Viegen,et.al.,1998) costs R200 and is available on CD-ROM with an accompanying manual. The *Population Atlas of Kenya* (Fox,1995) costs US\$160 and is accompanied by a User's Reference manual.

If there are users in the target African countries, trained enough to use these digital projects, there should be enough people to coach these countries to produce their own digital products.

4.5 An appraisal of the utility of digital atlases in Africa

Each producer appears to have had a different vision for the development of his/her atlas. For the

producer of the *Digital National Atlas of Tanzania* (Shand, 1997), the idea of contributing to the development of Tanzania was what drew him to start work on his pilot study for the atlas. He hoped that the atlas would serve "as a general national resource for administrators, government officials, teaching and research" (Shand, 1998:pers.comm.). His approach comes from knowing the benefits of a digital database in the developed world context, and seeing a role for it in Africa. The *Population Atlas of Kenya* (Fox, 1995) grew out of existing research in the hope of providing "educational institutions (esp. in Kenya) and the broader research community with an electronic database" (Fox, 1998:pers.comm.). Both of these producers see a positive role to be played by digital atlases in the African context.

The producer of the *Digital National Atlas of Tanzania* (Shand, 1997) notes that there are so few African digital atlases existing at present that he finds it difficult to make any constructive conclusions about their actual utility. He does note that the existence of a national digital atlas would aid the exchange of digital data for regional projects within a country and serve as a source for more detailed regional atlases. In Shand's opinion, the "use of digital atlases in Africa is a vital component of national development and would be a valuable tool for users within and outwith each country" (Shand, 1998:pers.comm.). In his experience the digitizing of maps and atlases in Africa has not been specifically for analysis and decision support but for the production of hard copy map sheets and atlases. To the public eye the format remains unchanged, but to the producer updating these digital maps and reproducing them is much easier. Shand notes that atlases in this case are available as non-editable raster products on the Internet or CD-ROM. The Department of Land Use and Planning in Mbabane has used IDRISI to produce hard copy maps of land use. Analysis is not carried out due to a lack of manpower, but the maps produced serve their purpose fairly well.

In Fox's opinion, digital atlases have helped in more applied research, particularly into population and environmental issues in Africa. The *Eastern Africa Atlas of Coastal Resources: Kenya* (UNEP, 1998) has been created to plan for sustainable utilization of Africa's coastline. Whilst the database will be used to aid planning and decision making, hard copy maps have been produced as well. This atlas marries the two uses of digital atlases in Africa envisaged by Shand and Fox. An additional use mentioned by Fox, which may seem less obvious, is the examination of political trends which have been carried out for

Kenya, South Africa and Lesotho. For South Africa and Lesotho, much data from *ENPAT* (DET,1998) was used, with some very interesting trends emerging.

At the start of production for the *Population-Environment Atlas of Swaziland* it was hoped that the atlas would be used by the Census Department to improve the efficiency of data management and provide a means of visually representing population patterns. Seeing the work and initial success of the digital mapping project in July 1998 was encouraging; there is a real possibility that data flow between the various government departments could be fostered. A group of people have been trained and are now skilled in data capture techniques. In the future, analysis will become a priority for use in projects such as the electrification of rural schools. With a locally trained workforce, there exists the possibility of continuity without experts being posted to another country leaving an ill trained workforce behind. A digital national atlas holds the potential to aid problem solving.

Perhaps the best way to demonstrate the potential utility of digital atlases in Africa is to take Swaziland as an example, comparing a traditional atlas of the country with the *Population-Environment Atlas of Swaziland*. With the aim of trying to obtain some examples of traditional paper atlases for the country, a search for commercially available atlases was conducted. The only atlas available in the shops in Mbabane in December 1998 was *The Atlas of Swaziland* produced in 1983 by A.S. Goudie and D. Price Williams. Looking through the atlas, the layout is in monochrome and is printed on a coarse paper; unlike many of the present day atlases printed for the United Kingdom or Europe for example. All the standard map information has been shown in this 90 page publication, accompanied by some interesting queries!

Looking at examples of some of the maps displayed in *The Atlas of Swaziland* (Goudie and Price Williams,1983), immediate advantages of digital atlases become apparent. In **Figure 4.1**, painstaking line hatching has been used to depict relief. With a digital atlas, a more detailed map can be created more quickly, for example in the form of a generated TIN. The TIN created for Swaziland can be seen in **Figure 4.2**. The degree of detail evident can be produced within a matter of 20 minutes. The three-dimensional impression vastly improves visualization. The creation of a map indicating relief through the

use of contours as seen in **Figure 3.40** can also be carried out in ArcView with relative ease.

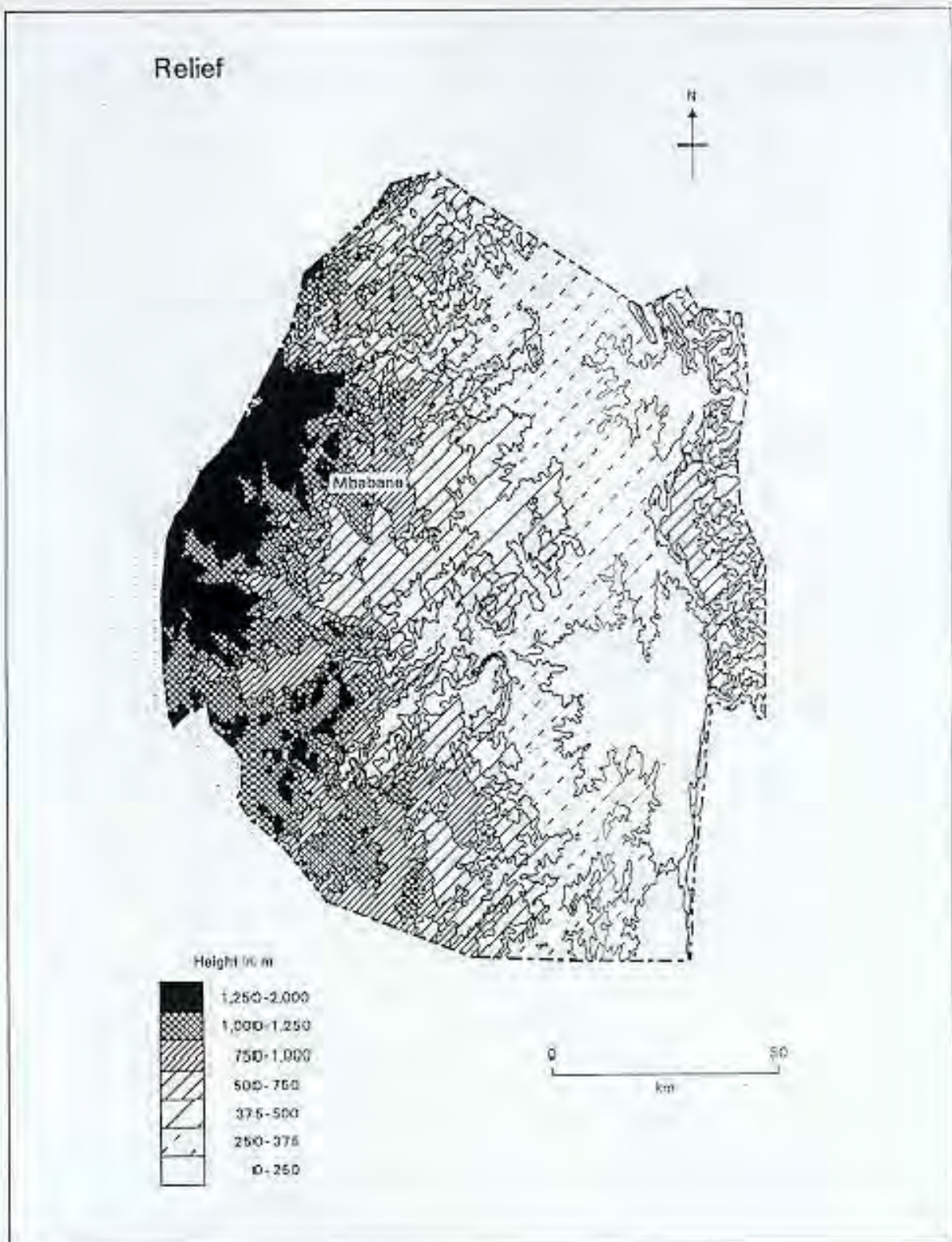


Figure 4.1: Relief (Source:Goudie and Price-Williams,1983,p16)



Figure 4.2: Triangulated Irregular Network (TIN) of Swaziland showing elevation data

In **Figure 4.3**, the representation of the country's soils relies on identification through lettering and line hatching. There is little doubt of the improvement in cognitive understanding that the use of colour makes. In the digital environment one has the opportunity to alter the map parameters until the ultimate combination of colour or fill styles is reached. Many maps lose their ability to communicate when poorly assigned colours or symbols are assigned. This is another reason why producers of digital maps and atlases should not be total newcomers to the spatial environment. As a trained cartographer, Shand is likely to produce some of the best maps. Difficulties were experienced in the choice of colour and symbols on several occasions during the production of the *Population-Environment Atlas of Swaziland*.



Perhaps one of the most interesting examples is the 'Tourist facilities' map which can be seen in **Figure 4.4**. Using this map, tourists may get a general idea of where to head to reach a nature reserve, but the symbols are very generalised in their placement. Interactive maps in the *Population-Environment Atlas of Swaziland* could show visitors the delimitation of the various nature reserves and positions of the areas of natural beauty with the option of viewing colour photographs of certain areas (See **e:\Atlas\Environ\reserves.shp** and **e:\Atlas\Infra\tour.shp**). Although the coverage in the *Population-Environment Atlas of Swaziland* does show the occurrence of hotels in the Kingdom, it does not display the number of beds available in each; *The Atlas of Swaziland* (Goudie and Price-Williams, 1983) does. This is data which could be updated and input into the digital atlas.

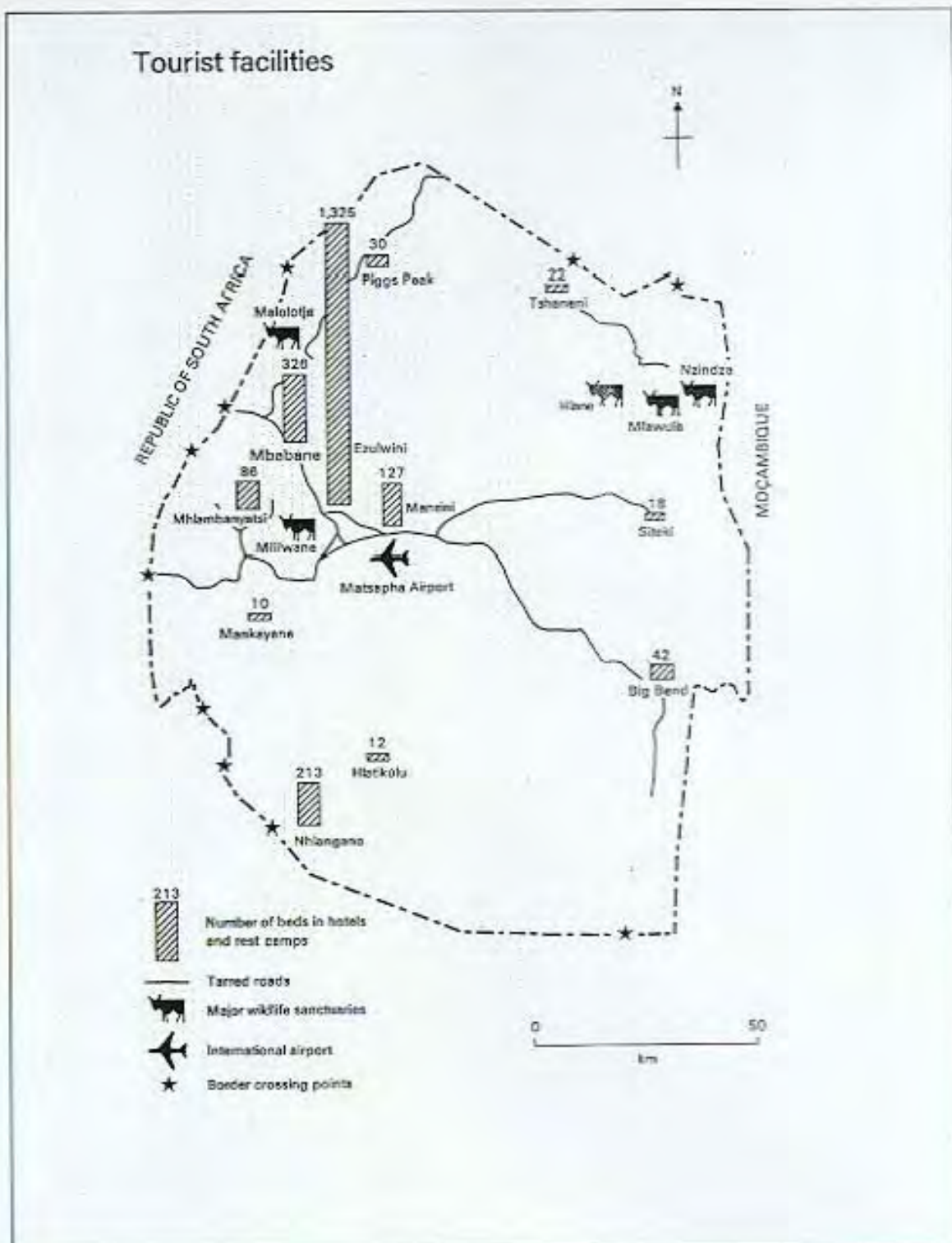


Figure 4.4: Tourist Facilities (Source:Goudie and Price-Williams,1983,p62)

In *The Atlas of Swaziland* (Goudie and Price-Williams, 1983), there are a couple of maps displaying the type of queries one might expect to carry out using ArcView. It is easy to fall into the trap of assuming that this type of mapping was impossible before the advent of GIS. Although still in monochrome and difficult to reproduce, the general information is there. In the 'Rail network' map seen in **Figure 4.5** for example, the draftsmen have worked out the areas which lie within 20km of the national railway line. Likewise in **Figure 4.6**, areas further than 20km from major hospitals have been mapped. These distances would have been worked out manually, so the type of accuracy attainable using a GPS and GIS is just not achievable. Purely out of interest, the same query was carried out using data from the digital atlas to see if a similar pattern existed. The result is visible in **Figure 4.7**.

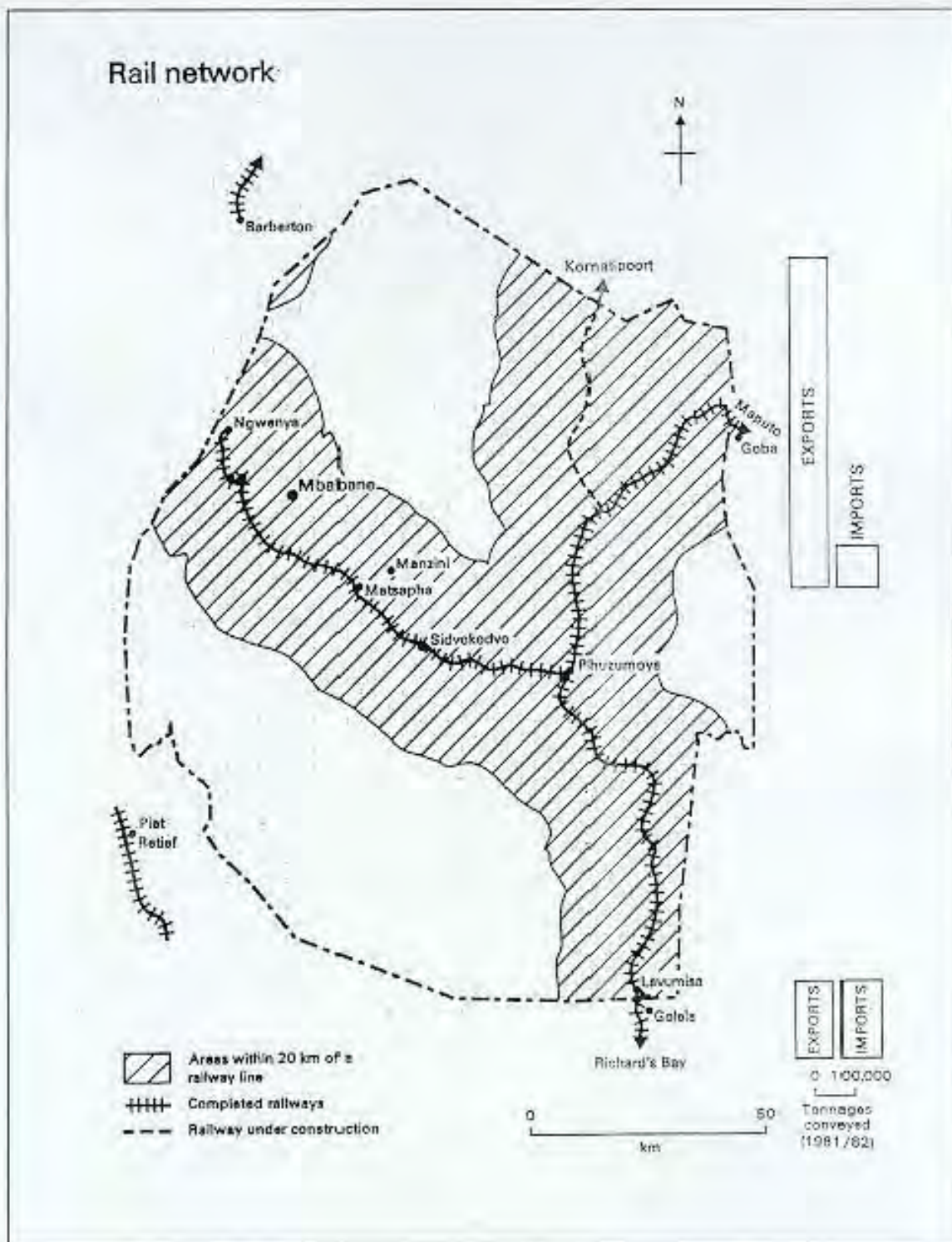


Figure 4.5: Railway Network (Source:Goudie and Price-Williams,1983,p68)

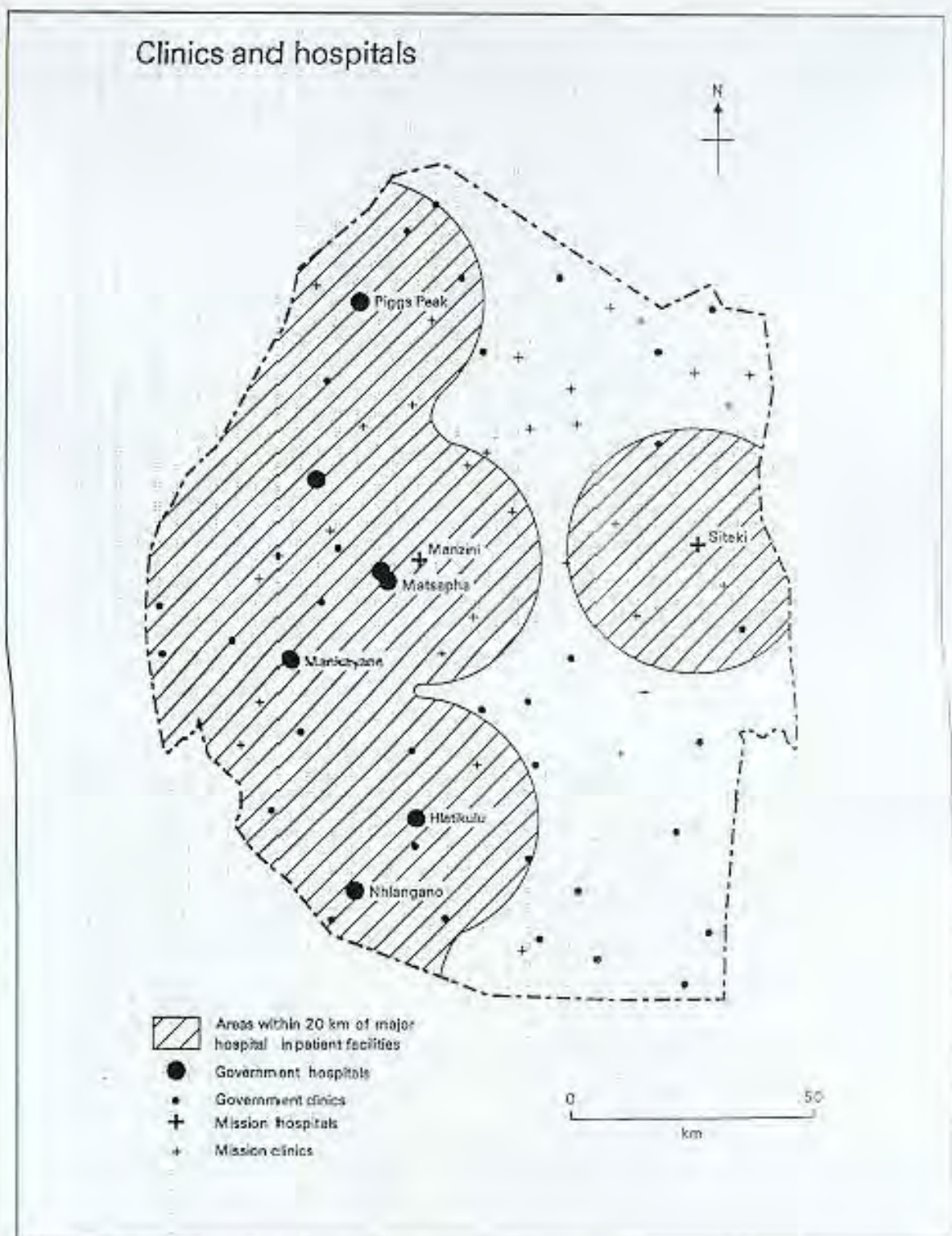


Figure 4.6: Clinics and hospitals (Source:Goudie and Price-Williams,1983,p84)

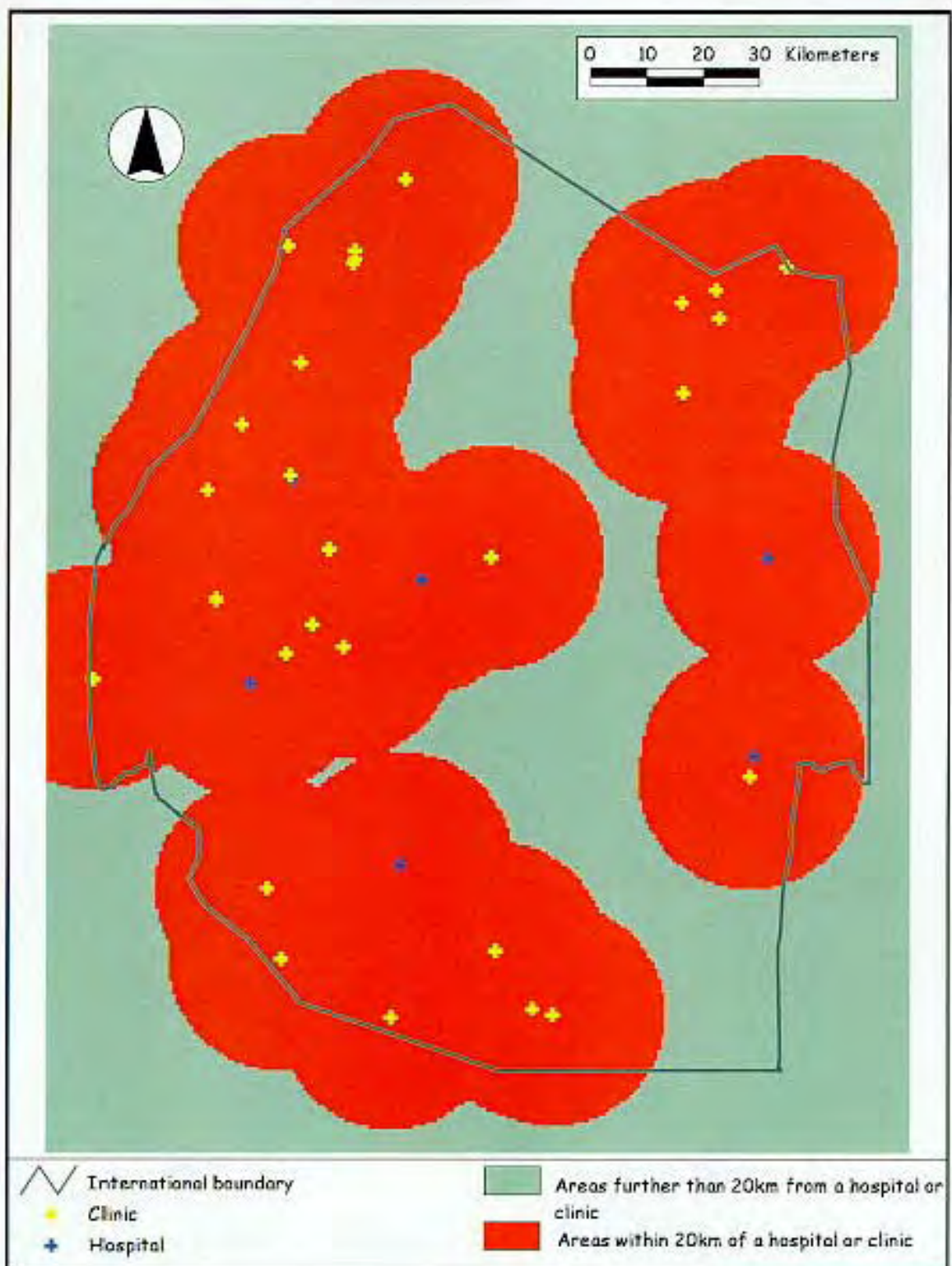


Figure 4.7: Accessibility to hospitals and clinics (1991)

Five selected queries carried out using the data set of the *Population-Environment Atlas of Swaziland* will now be presented in an attempt to demonstrate the capabilities of mapping in the digital environment. The five queries will involve two distance mapping queries, two surface creation queries, and one three-dimensional display using the 3D spatial analyst. Although distance mapping appears to have been managed well in the traditional environment, some of these examples show the ease with which more complex queries and displays can be achieved in a short amount of time.

It is necessary to keep in mind that since the 1997 census data has been unavailable, the population figures being used are twelve years old. There is the possibility that the patterns of distribution may have altered. The base maps from which features such as police stations and roads were captured from, are seven years old. It is highly possible that additional features now exist. The general utility of the atlas however, can still be made apparent.

Query One

Figure 4.8 shows the results of the first distance mapping query, using the enumeration areas as a base. The aim of the query is to highlight areas of the country in which people over the age of 65 are living further than 10km from the nearest hospital or clinic. If so desired, the reader can use the accompanying CD-ROM to access the data and follow the steps below. The query was carried out in ArcView 3.0 as follows:

1) Open a 'New Project'

Click on 'View' in the project window and choose 'New'

Open the enumeration areas (enum86.shp) and the medical cover (medical.shp)

2) From the toolbar menu, click 'View' and then 'Properties'

Choose 'Projection', then 'Custom' (This places the view into an Albers Equal-Area projection necessary for distance queries)

Click 'OK'

Choose 'kilometers' for the distance units

Click 'OK'

3) Make sure enum86.shp is active

Click the Query Builder icon

Select the following: $([M_65plus] \leq 283) \text{ and } ([F_65plus] \leq 353)$.

Make medical.shp active

Click the Query Builder icon

Select the following: $([Medical_id] \neq 11)$. This will select all hospitals and clinics; Health centres (id=11) are omitted as they are not perceived to have adequate supplies or equipment.

Make the enumeration areas theme active

Select 'Theme' from the toolbar menu,

Choose 'Select by Theme',

Choose 'Are Within Distance Of',

Choose 'medical.shp',

Choose '10km'.

Click 'New Set'

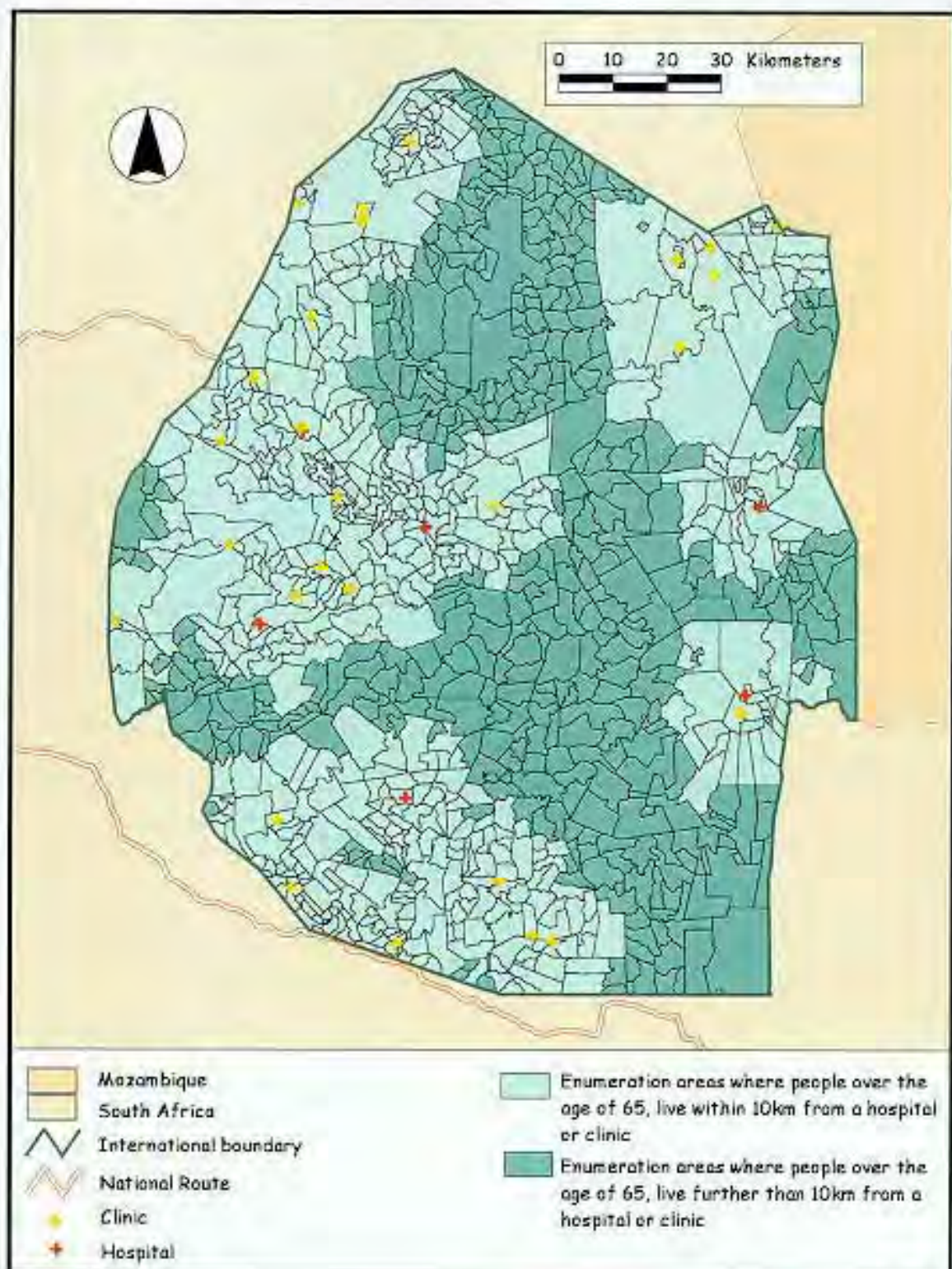


Figure 4.8: Accessibility to hospitals and clinics for people over the age of 65

Query Two

As violent crime is a steadily increasing problem in Swaziland, it was deemed appropriate to look at the pattern of police station distribution. Again, using the enumeration areas as a base map, areas which were further than 20km from the nearest police station were highlighted. Population density could of course influence the decision to build more police stations in those areas which appear to be lacking. **Figure 4.9** shows the results of this query.

The query was carried out as follows:

- 1) Open a new view
- 2) Open the enumeration areas (enum86.shp) and the police station (police.shp) covers
- 3) Select 'View' from the toolbar menu.
Choose 'Properties', then choose 'Projection'.
Click on 'Custom' to make sure the covers are in an Albers Equal-Area Projection. Click 'OK'
Choose the distance units 'kilometers'
Click 'OK'
- 3) Make the enumeration areas active
- 4) Select 'Theme' from the toolbar menu
- 5) Choose 'Select By Theme'
Choose 'Are Within Distance Of'
Choose 'Police.shp'
Choose '20km'
Click 'New Set'

(The selected enumeration areas will be those which are within 20km of the nearest police station)

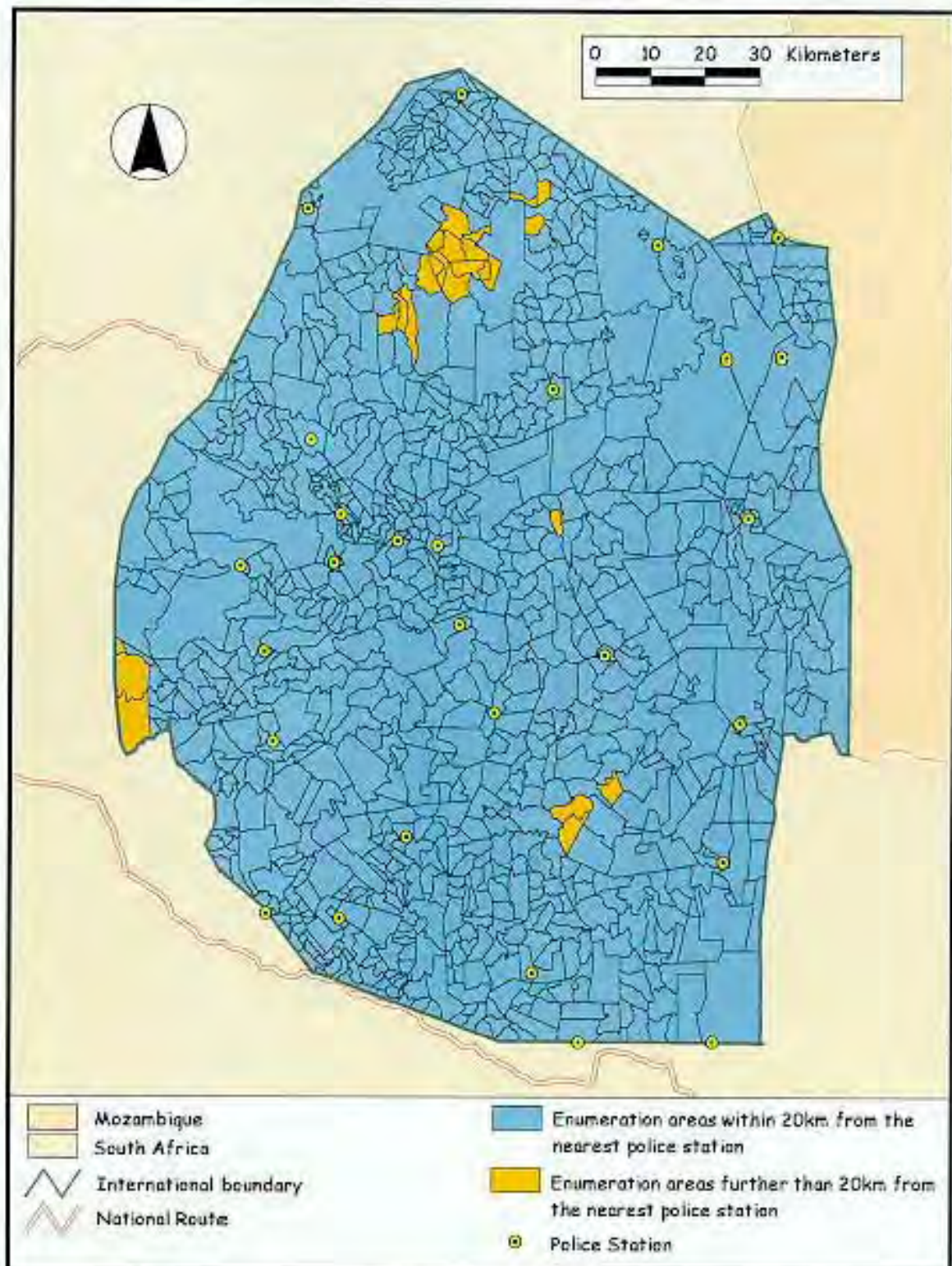


Figure 4.9: Accessibility to police stations by enumeration area

Query Three

For the third query, a problem was chosen which required the use of surface creation in ArcView 3.0. As the government has expressed interest in the tourist potential of the country, it was thought to be relevant to look for potential sites to build new hotels. It is important to note that the query conditions used are subjective. To achieve the most accurate results, a professional land developer should use the system..

To carry this query out several conditions were thought to be necessary. To ensure a water supply for the development, areas close to a perennial water supply were identified. The South African 1:500 000 Topographic data (ComputaMaps,1997) cover of rivers for South Africa was opened and the international boundary of Swaziland was clipped to the cover. Suitable climatic conditions needed to be identified. Areas which had a mean annual temperature above 15 degrees Celsius and below 25 degrees Celsius and an annual rainfall amount between 450 - 1000 mm were selected. To determine aspect for the country, the surface creation tool available using the 3D analyst, was used and an aspect cover was generated. From this, it was possible to choose sites which had the flattest land for building on. Once the requirements had been selected from the relevant covers, they were overlaid to find the most suitable areas. Potential sites were chosen manually and the line of sight tool was used to determine which site had the best view of the surrounding mountains. The result can be seen in **Figure 4.10**.

The steps used to complete this query have been outlined below. They can not be followed on the CD-ROM, however, as some of the covers used are from commercially available data sets.

A) To select areas with suitable climatic conditions the following query was carried out:

1) Open the thermal cover (Temp.shp) and the rainfall cover (moisture.shp)

Double click on temp.shp to open the Legend Editor

At 'Legend Type' choose 'Unique Value'

In the 'Values Field' choose 'Mean_annua'

Click 'Apply'

Double click o moisture.shp to open the Legend Editor

At 'Legend Type' choose 'Unique Value'

In the 'Values Field' choose 'Annual_rai'

Click 'Apply'

2)3) Select 'View' from the toolbar menu.

Choose 'Properties', then choose 'Projection'.

Click on 'Custom' to make sure the covers are in an Albers Equal-Area Projection. Click 'OK'

Choose the distance units 'kilometers'

Click 'OK'

3) Make the Temp.shp theme active

Click the Query Builder button and build the following expression -

([Mean_annua]= "15.0-25.0")

Save the result as a shapefile (e.g. tempque)

Make the moisture.shp theme active

Click the Query Builder button and build the following expression -

([Annua_rai]>= "450 - 550") and ([Annua_rai]<= "850-1000")

Save the result as a shapefile (eg. rainque.shp)

3) Make the 'rainque.shp' theme active

Select 'Theme' from the toolbar menu

Choose 'Select by Theme'

Choose 'Contain the Center of'

Choose 'tempque.shp'

Make a shapefile of the result, (e.g. temrain.shp)

B) To select all flat areas, the following query was carried out:

1) Open the aspect (aspct.shp) cover

From the toolbar menu choose 'Analysis', then choose 'Map Query'

Build the following expression -

Aspect of Crtin1 = -1 (Crtin1 is the Triangulated Irregular Network which has been created for the country. All areas which the computer has assigned the figure -1, are flat areas.)

Click 'Evaluate'

All flat areas are now selected (Map Query 1).

C) To select potential hotel sites, the following queries were carried out:

1) Open temrain.shp and Map Query1

A copy of the hotel cover (pothot.shp) was opened and placed in edit mode. The schools (school.shp) and towns (towns.shp) covers were also opened to guide the choice of potential sites. Potential sites were selected by adding points to the pothot.shp theme in areas which were within the selected climatic region and were flat. 16 potential hotel sites were selected.

Open pothot.shp (This cover holds existing as well as potential hotel sites)

Open the Query Builder and build the following expression:

[pothot_id] = 0 (All potential sites are selected)

Make a shapefile of the potential sites (e.g. 2pothot.shp)

D) To select all sites within 0.2km of a perennial river, the following query was carried out:

1) Open the river.shp theme as a line cover

Double click on the rivers.shp theme to make the Legend Editor active

For Legend Type, choose 'Unique Value'

In the Values Field, choose 'Type'

Make the 2pothot.shp theme active

Select 'Theme' from the toolbar menu

Choose 'Select by Theme'

Choose 'Are Within Distance Of'

Choose 'Rivers.shp'

Choose '0.2km'

Make a shapefile from the selected features (e.g. 3pothot.shp)

5 potential sites are highlighted.

2) Open the TIN of the country (crtin1): (it takes approximately 10 minutes to open)

Overlay the 5 potential sites (3pothot.shp)

Click on the line of sight tool and draw lines of visibility from each site to choose the one with the furthest views of mountains.

This query should be seen as an example. More work would need to go into the selection of potential hotel sites. Population density, land tenure and soil type are just some of the additional factors which would affect the choices made.

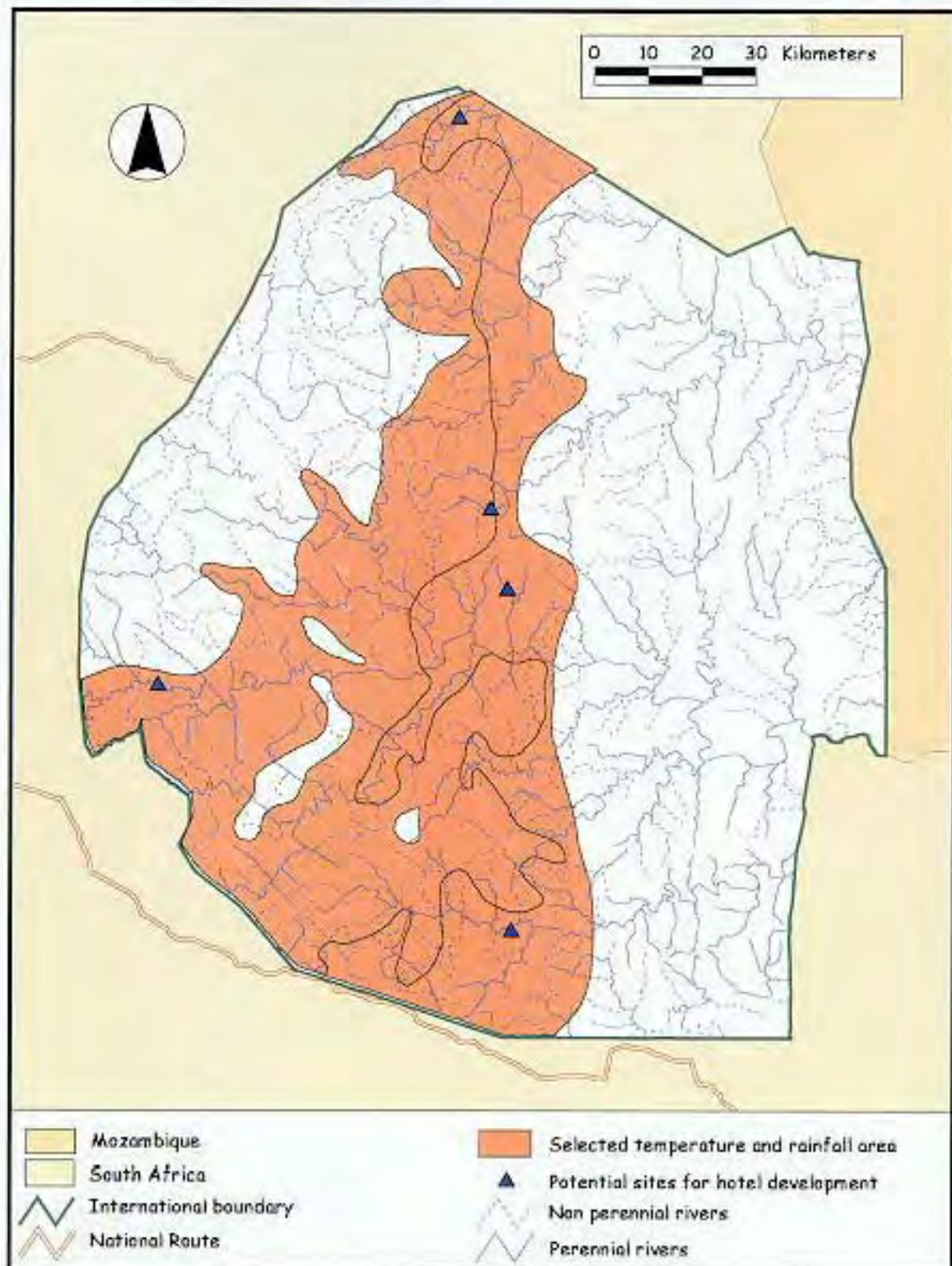


Figure 4.10: Suitable sites for proposed new hotel developments

Query Four

Cellular telephones were introduced to Swaziland in November 1998. To experiment with the capabilities of the atlas, it was decided that a cover identifying potential sites for MTN cellular towers would be produced. To carry this out, a point cover was created in PC ARC/INFO, selecting sites which were thought to be suitable for these towers. Areas on high lying land were selected in the hope that the signal would be as widespread as possible. To see the results of these choices, a Viewshed Analysis was carried out, using ArcView 3.0 with the 3D Spatial Analyst extension. (see CD-ROM **e:\Atlas\Cover\Query4**).

Query Five

As an example of the visual benefits available using the 3D Spatial Analyst extension, a 3D image of the population density for the country was created. The result may be viewed on the CD-ROM at **e:\Atlas\Cover\3ddens.jpg** or **e:\Atlas\Cover\3ddens2.jpg**. The two images display the same information, but represent two different exaggeration values.

If the reader would like to re-create the effect, the following steps can be taken:

1) Make sure that the spatial analyst and 3D extension dongles are connected to the computer

2) Click the '3D Scene' icon in the project window and click on 'New'

Open the theme enum86.shp from the CD-ROM

From the legend editor choose 'Graduated colour'

From the Classification field choose 'Density'

Click 'classify' and change from 5 classes to 20 classes. Click 'OK', then 'Apply'

Open the theme by 'clicking' on it and see the image in 2D, on its back.

3) From the toolbar choose '3D Scene', then choose properties

At the 2D projection window, click 'Select', then 'custom', then 'OK'

Choose a 'Vertical exaggeration factor' of 6 (as an example)

Click 'OK'

4) From the toolbar choose 'Theme', then select '3D properties'.

In the 'Extrude features by value or expression' box, create the query $[Density]*6$

In the 'Extrude by' box, choose 'Adding to base height'

1) Click 'Apply' and wait for the image to appear

At this stage it is possible to manipulate the display by using the navigator icon.

The queries shown here are a small selection of what could be done with the atlas. The possibilities would be even greater if additional data sets developed by other organizations were incorporated into the atlas.

There is no doubt that the *Population-Environment Atlas of Swaziland* could be used for tourism, especially if extra information was added with regards to hotel quality and leisure activities. If made available in part on the Internet, the beauty of the country could be displayed through scanned photographs linked to clickable areas on the maps. With a simplified Graphical User Interface, tourism offices in South Africa could be supplied with the atlas to provide immediate access to overseas visitors possibly, attracting interest for Swaziland. Similar information setups are already available in Johannesburg International Airport for example where people can use touch screens to get information on tourist areas.

Due to graphic capabilities, there is a potential role for digital atlases in education in Africa. There is no easier way to explain concepts than through the use of interactive methods. If computers are available, teachers could use interactive atlases to explain map projection and physically show the effects of different projections on maps. Atlases could be modified according to the age of the user, perhaps helping children learn the names and functions of towns in their country. What better way of understanding one's country than to test one's knowledge by clicking on a town, filling in key words describing the town's function and being corrected by the computer. At a higher level of education, digital atlases could be used to show agricultural students, areas where agricultural potential is not being achieved, or the effects of certain farming practices on the land over a 20 year period.

Census departments could make use of a digital atlas to help store, manipulate and display census results. Census data is of little use when presented as reams of figures. Looking at the census volumes published in 1986, the producers have realised this and have included some maps, the quality of which is quite poor (see **Figure 4.11**).

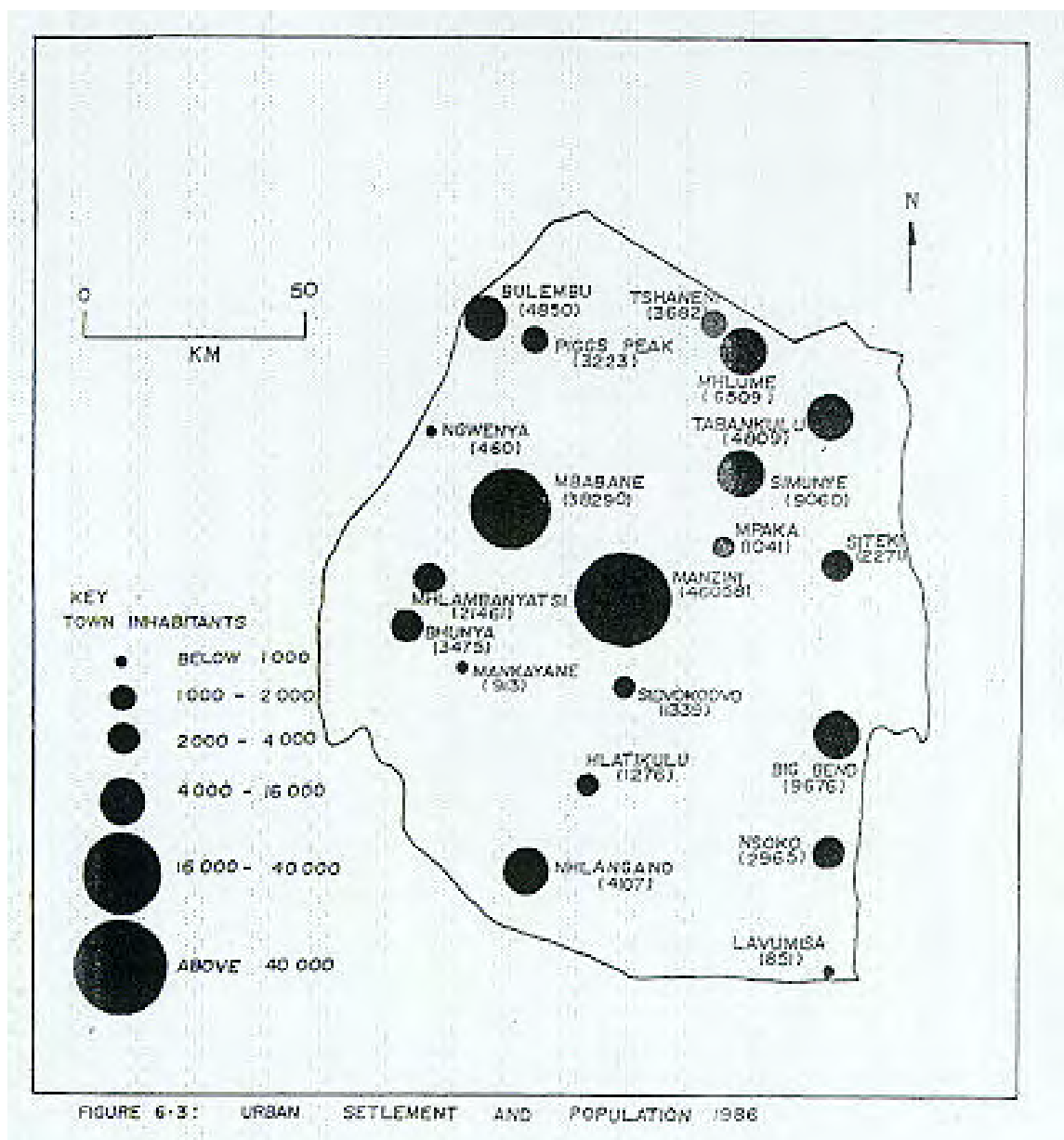


Figure 4.11: Urban settlement and population (The Kingdom of Swaziland,1986)

As the data for the *Population Atlas of Swaziland* has not been groundtruthed, the locational accuracy of the point and line features is uncertain. There is no doubt that the municipalities in Africa could make use of digital atlases. Whereas data sets often relate in detail to a specific area, national atlases cover the entire country making sure that investigations into service provision are not confined to a few areas; all too often people living in rural areas are forgotten. Although expensive, groundtruthing would decrease reliance on the accuracy of source maps from which data has been captured possibly increasing the

reliability of queries carried out.

An Atlas of Malaria is already being developed for the African continent as mentioned in Chapter Two. The project is going to take time to complete. In the meanwhile, those countries which have the capabilities to start data capture of their own which could contribute to the African database, should start. National digital atlases could be considered as having the bare bones of such research into which additional data sets could be added. Malaria is not the only sickness to plague Swaziland, TB and dysentery are still killers. AIDS of course is pandemic. One consideration might be to use the national atlas as the basis for a national epidemiology atlas. If factors affecting the spread of TB and dysentery are fed into a database and high risk areas are mapped, diseases can be monitored more easily with patterns of illness occurrence made more apparent. Many people are killed in Swaziland by lightning strike. It has been established that areas with a high granite rock content are more susceptible to lightning strikes. If such areas could be identified, action might be possible to reduce risk of injury and damage.

Chapter 5:

Guidelines for the production of digital atlases in Africa

"...one of the challenges of the scientists constructing this system is to be flexible enough to envision future uses - even ridiculous ones that can't be seen today" (Huxhold, 1991:xiv)

5.1 Introduction

In this chapter, possible guidelines for the production of digital atlases in Africa will be suggested. Personal experience with the production of the *Population-Environment Atlas of Swaziland* has been used to help develop the guidelines. The opinions obtained from some of producers and the literature surrounding the research have also been used. The guidelines are intended for governmental as well as non-governmental organizations, should either wish to embark on such a project.

5.2 Setting guidelines for atlas production in Africa

One has to be realistic about the situation which Africa finds herself in with regards to political instability, a lack of skilled manpower, and inadequate infrastructure. Many people do not have access to running water, let alone a PC. Although the possible benefits of an atlas in an interactive environment are evident, if the basic materials are not available to the general public or government agencies, one has to question whether or not the costs involved in developing such a project would be justified. Before embarking on a digital atlas for a country there are several guidelines which could be considered.

5.2.1 Identify a need for the proposed atlas

The creation of a national digital atlas requires skilled manpower, sufficient computer facilities, and digitizing or scanning equipment. The expense of fulfilling these basic requirements is considerable making it important to ensure that the atlas will be used now and in the future.

Embarking on a project as a status symbol or without any specific future utility in mind is wasteful of resources. As far as possible, support for digital atlases should be expressed by the people who will be making use of them; if this dedication is not secured from the start, the project may not be successful.

Identifying a **need** for a national digital atlas should therefore be a priority. If a rural school has access to electricity and a computer for example and government intends to provide a copy of the atlas, its educational benefits could be considerable. By providing a copy of the atlas to travel agencies around the world, the tourism industry in the country could be boosted. If the creation of an atlas was to serve as a basis for mapping of disease and relevant medical facilities in the country, then improved provision of health facilities could result. Having identified a need for the atlas, the next steps involve an assessment of whether or not the country has the necessary facilities and environment for production.

5.2.2 Assess the political situation in the country

For any project to reach a successful conclusion, the support of a stable everyday lifestyle is essential. Civil wars plague Africa and in countries where it is not safe to venture into the bush, fieldwork and groundtruthing for digital work would be dangerous. Countries need to be realistic about the potential of political instability interfering in projects and decide whether or not it is feasible to begin work.

5.2.3 Assess the available infrastructure

The most important infrastructural ingredient is a constant "clean" supply of electricity. In many African countries, power failures and power fluctuations are common. UPS systems and computers with in-built battery packs can reduce interruptions to work, but continuity of electricity supply should be investigated through the use of generators, and/or solar power.

5.2.4 Assess the equipment already available

Before deciding to purchase the latest software and hardware, it would make sense for a qualified person such as a GIS specialist to evaluate what is already available within the organization. Older equipment is not necessarily obsolete and can be incorporated into more modern environments. An example is the use of the photogrammetry stations in the digital mapping project in Mbabane, discussed in Chapter One. The millennium "bug" is also a factor for consideration when equipment is being evaluated.

The quality of computer output in terms of screen graphics is constantly being improved upon to enhance visualization and there is the possibility that older computers may not provide a satisfactory idea of what

is attainable with a digital atlas. This may make the purchase of new equipment unavoidable.

It is suggested by Odedra (1992) that the underutilization of existing equipment is directly related to manpower shortages and a lack of available computer training courses. This is exactly the case in the Census Department in Mbabane. The Census Commissioner noted that the computers were available for mapping, but the department did not have enough money to send staff away for training. If this is the case in a country wanting to embark on such a project, costs involved in recruiting more manpower need to be carefully outlined.

5.2.5 Assess the level of manpower available

If a digital atlas is to be of continual use to the country it needs to be updated and evaluated regularly. Skilled manpower is needed to produce the atlas as well as to maintain and manipulate it. Gardner (1993) notes that "many projects have come to a sudden halt when the consultant leaves the project, especially when there has been no attempt to ensure continuity through the transfer of skills to a local, in-house team" (Gardner, 1993:14). The project leader of the cadastral database made mention of the fact that he was the last expatriate consultant in his department and was skeptical of successful continuation after he left (Johnson, 1998:pers.comm.). Producers need to be sure that there will be enough trained people for continuation of the project. The best scenario would be to ensure that a local team is trained to run the project.

5.2.6 Motivate the entire department

A commitment to the project from all levels in the project department is essential for success. For maximum motivation, Campbell (1994) suggests that all staff need to be given the opportunity to comment on the project design. They need to be shown examples of the benefits achievable with the product and told that it will take some time before the results are visible.

Judging from experience in producing this atlas, it would also be necessary to point out that technology is not infallible. The process can be tedious and the results are not always what is expected. Giving a realistic outlook would mean that no misconceptions would be fostered, and hopefully motivation would

be maintained.

5.2.7 Establish adequate funding

It is essential to establish the **total** amount of money available for the production of a digital national atlas, to ensure that there is enough to complete the project. If possible, it is suggested that substantial funds are raised locally, to ensure national commitment.

5.2.8 Create an environment conducive for atlas production

Three main components of a GIS need to exist, should the full potential of a digital atlas be achievable. The first is the computer hardware, the second is the application software and the third is a conducive environment. The "optimisation of system design and use must include consideration of physical and mental characteristics of users as well as factors related to the work tasks themselves, the system functionality, the physical environment and the organisational context" (Turk,1993:15). All these factors will have a significant role to play in determining whether or not the production and use of digital products such as national digital atlases in Africa, hold any chance of success.

i) System design; considering the physical environment

Optimisation of productivity in the working environment has been closely examined by several researchers. Lessons can be learnt from this research and applied to the production of digital atlases. Turk (1993) reports on studies which have been carried out to find the optimum position for human-computer interaction with minimal physiological stress on the body thereby creating greater productivity. The cost of acquiring ergonomically designed equipment such as customised computer chairs or specialized keyboards for example needs to be added to the budget of an atlas production project. Although it is possible to capture data using a regular stool to sit on, long hours spent at the computer or digitizing table as a regular occupation could be detrimental to the operator's health.

An examination of the existing physical working conditions needs to be carried out. The physical environment needs to be appropriate for the production of a digital atlas to ensure quality and successful utility. Working in a noisy environment is wholly unsatisfactory when trying to capture data. In the

production of the *Population-Environment Atlas of Swaziland*, being interrupted whilst digitizing the enumeration area lines was frustrating. Errors created by interruptions, can easily be eliminated through careful placement of the equipment and its operators. The equipment ideally needs to be set up in a room of its own, where the operator is not distracted by other people's movement or conversation. Temperature and lighting need to be assessed and set according to the equipment and workers needs.

ii) System design; considering the organizational context

According to Turk (1993) it is often the issues surrounding the organization of a project that limit the success of GIS projects. In the data capture process in particular, it is suggested that a work program be set up whereby the person digitizing works for an hour and then does something else for fifteen minutes. Rest whilst digitizing is essential to keep the concentration going, and error creation to a minimum.

5.2.9 Acquire appropriate software

It is suggested that policy guidelines (discussed in more depth in section 5.2.11) should be followed when choosing software or hardware. If the software and accompanying manuals are not available in the mother tongue of the operator, finding a way to allow its incorporation would be highly beneficial to the production process.

5.2.10 Acquire appropriate hardware

From the experience of producing the *Population-Environment Atlas of Swaziland*, the use of a Pentium PC or higher should be used to reduce production times. A 486 PC was used initially, but in hindsight it is realised how slow it was and how liable it was to crash.

5.2.11 Adhere to national policy guidelines

If the equipment needed for the creation of the atlas has to be purchased, it is essential that advice is sought to identify the most appropriate hardware and software available. As has been outlined in Chapter

Two, many African countries do not have policy guidelines with regards to the importation of computer products. If this is so, it is suggested that guidelines should be developed as soon as possible. Erlank et.al., (1993) suggest that there are several prerequisites for effective technology transfer, namely a basic supply of skills and expertise and careful control over technological choices. Rapid installation of computers is common in African countries, but for the most part the software is not being exploited to its full capacity. A common problem with the type of hardware and software being acquired, is that it is sometimes unsuitable. Vendors take advantage of poor IT knowledge, and rely on the fact that advice from the developed world is treated as gospel (Ojo,1993).

Korea has set out five guidelines for the importation of foreign technology, which some African governments might consider. Kasongo (1993) outlines the five questions which have to be answered, namely Adoption, Absorption, Diffusion, Assimilation and Adaptation. Under 'Adoption', one has to answer how, where, when and with what consequences the technology will be implemented. 'Absorption' questions how the imported technology can be learnt and embedded into local systems with the possibility of being improved upon. 'Diffusion' looks at the nature of the spread of technology between firms, the effect it will have on production techniques and knowledge (Kasongo,1993). 'Assimilation' determines the degree of integration with local supply inputs and finally 'Adaptation' assesses technological change as a result of using imported techniques. The five questions once answered would provide the government with a clear report on the direction the importation of technology will take them. By adhering to policy guidelines, informed decisions on the most appropriate technology can be made. Ojo (1993) notes that guidelines could also to ensure that there is some sort of continued user support should problems be experienced with the imported equipment. Continued user support should be a pre-requisite for the purchase of hardware and software.

5.2.12 Data standards must be drawn up; data compatibility

Considering the cost of data collection there is little point for a national digital atlas to be developed in isolation from any other digital work that has been carried out. To ensure long term data sharing between departments and organizations, compatibility is important. If the national digital atlas has not been

captured in enough detail for one particular user, he should be able to add his own data to it without any significant problems. Digital mapping standards need to be outlined and adhered to.

5.2.13 Determine accessibility to data

One of the main ingredients of any electronic atlas, is data; both digital and non-digital. In Africa very little digital data exists for many countries and available non-digital data can be problematic to attain. Restricted access has the potential to increase the costs of atlas production significantly.

Cassettari (1993) notes that information collected by central government is in many countries carefully controlled. In some cases, topographic maps produced are not permitted for public use. In cases such as this one wonders what chances a digital atlas has of being seen by the public. Some countries protect their data through law for reasons ranging from national security and invasion of privacy to confidential commercial or financial information (Cassettari, 1993). In Europe, the public have access to information on the environment, available at a cost.

It is suggested that before embarking on a digital atlas, the degree of data available and access to it is ascertained. If the volume of data to be captured is quite considerable, a feasibility study should be carried out.

5.2.14 Ascertain the completeness and accuracy of base maps available for data capture

As mentioned in previous chapters, hard copy maps in many African countries are usually old. It is up to the producers to ascertain whether or not it is worth relying on these maps for data capture or supplementing the data with groundtruthing and further field mapping.

5.2.15 Decide on the level of detail to be included

The intended use of the atlas will usually determine the level of detail to be included. Capturing data in detail is expensive. "We need to determine what level of abstraction is valid and acceptable in what set of circumstances so as to avoid unnecessary escalation of costs and expectations among information

consumers" (Bishop,1994:64). If the objectives of the digital atlas are clearly outlined, subsequent users of the atlas will not be disillusioned. They will also know which data sets they will have to capture more data for should they need it.

5.2.16 Follow a data capture structure

To ensure a logical and complete data capture process, it is necessary to draw up a program to decide which layers will be captured first. The dates of base maps or attribute information should be noted so that the user knows how up-to-date the data he is working with is. Data sources should also be noted. Keeping a journal to note each step proved to be very useful in the production of the *Population-Environment Atlas of Swaziland*. One only realises the benefit of making a note of file names, for example, once the number of covers increases.

5.3 Guidelines to consider after production of the atlas

5.3.1 Establish copyright and liability

As digital work is a relatively new area for many African countries, much of the work is not protected by copyright and liability is not clearly understood. Used as a tool for planning and decision making, questions of data accuracy often arise in the digital environment. Work is rarely error free, and the user needs to be made aware of this. Epstein and Roitman (1990:34) suggest that the agency's liability should be established in case "the data is inaccurate, or even if accurate, the client misunderstands it and misuses it". To avoid unnecessary concern about the liability of the future use of data by individuals, advice should be sought on legal guidelines to attach to the data.

5.3.2 Create a national fee structure

Despite the nature of copyright where the owner has the right to decide on the cost of the data and whether or not data will be sold, in the case of a national digital atlas public access should go undisputed. A nominal fee structure should be set by the producers, to cover the costs of data capture. The fee should not exclude people from accessing the atlas on the basis of being unable to pay. Cassettari (1993) notes that high levels of cost may encourage infringements of copyright.

5.3.3 Decide on the method of data dissemination

Once a national database or national digital atlas is in place, ensuring universal access to it should become a priority. The development of the atlas could be advertised to the public so that they realise the product is being developed. To increase the user base, atlases need to be made available in a variety of formats. A national atlas could be made available for downloading on the Internet, whereby the user would be able to use the atlas interactively. For people who are not as computer literate, visual realism could have a big role to play; "the non-scientific audience wants abstraction minimised and information content maximised" (Bishop, 1994:6). Bishop (1994) provides an example of a 'virtual' flyover of Madagascar thirty years after deforestation noting that the visual results will communicate the damage more effectively than a ream of statistics or a static map series would. People without access to Internet facilities or without the necessary computer skills, need to be considered. The idea of a national digital atlas is that it should be available to the nation and this may involve certain modifications. For example if existing community information centres could be supplied with interactive technology as suggested by Woods (1993), and the user interface is simplified to make operation easier the potential for greater data dissemination exists.

5.3.4 Ensure that whatever patterns become apparent, none of the information is censored

Governments could be uncomfortable with some of the patterns that can be depicted using a national digital atlas (depending of course on what data layers have been included). For example a government which promotes itself on the provision of basic needs may not care for people to find out that the rural areas actually lack access to basic medical facilities. Campbell (1994) notes that "Information...embodies social and political meaning which makes some data holders cautious about allowing general availability" (Campbell, 1994:317). Keeping this in mind, the producers need to try and ensure that access to the atlas is not restricted.

5.4 Guidelines for atlas production and maintenance in Swaziland

5.4.1 Foster an indigenous work force

The benefits of having a skilled work force of local individuals are numerous. People who are familiar with the country have an advantage over those who are not. Working with coverages of the country they are more likely to notice subtle errors. During the creation of the forests cover, for example, a polygon representing Usutu forest, had not been closed. Initially, the absence of this large man-made forest went unnoticed. Looking at the cover in ArcView, the error was identified and could be corrected. It is evident from the digital mapping project in Swaziland that there is a small pool of local workers who are skilled in data capture (Simelane, 1998: pers. comm.). These skills should be nurtured and constantly updated. With this group of people, there is a good chance for the continued use and maintenance of products such as the *Population-Environment Atlas of Swaziland*.

5.4.2 Foster the development of analytical skills

To make full use of the atlas, an effort should be made to seek training in analysis for a number of employees. The atlas will not fulfil its full potential unless the data sets are queried.

5.4.3 Using the Population-Environment Atlas of Swaziland

The currency of the data in the *Population-Environment Atlas of Swaziland* should be focussed upon. Data relating to the 1997 population census, for example, should be input as soon as it becomes available. It is envisaged that the *Population-Environment Atlas of Swaziland* will be used as a basis for future work. Through the input of additional information, the country could start the development of a digital record of population information.

Greater detail could increase the potential utility of the atlas. Using the tourism information covers as an example, information could be improved upon through the linking of more images and descriptions. Costs per person at hotels, motels and lodges could be included.

5.4.4 Draw up data standards

Any information added to the atlas should be input by a central team of data technicians. This ensures

that a set standard of work is maintained. If additional data is going to be added to the atlas, it is imperative that data standards are adhered to. Data standards include deciding on what level of accuracy is acceptable.

It is suggested that source maps should be screened for inaccuracies such as unclear boundary definitions and over-generalisation of features. The use of the 1:250 000 topographic map for the country (1989) was found to be inaccurate in the capture of the country boundaries during the production of the *Population-Environment Atlas of Swaziland*. The use of this map as a data source should be limited to information which does not require absolute accuracy to within centimeters.

5.4.5 Encourage data flow between departments

The creation of guidelines for data dissemination should be established. Once in place, departments may feel more comfortable with the exchange of data.

Information generated by one department could be made available for viewing by other departments through its addition to the national atlas. An awareness of the data available in-house will reduce data duplication and may provide greater support for governmental projects.

Chapter 6: Conclusion

"a major advantage of GIS lies exactly in its ability to accommodate unanticipated needs."

(Chrisman, 1991:167)

6.1 Conclusion

Digital mapping systems and GIS have reaped benefits for the developed world since the late 1960s when Canada pioneered its land use information system. Realising the extent of efficiency attainable in the storage and manipulation of data using GIS systems, the rest of the developed world followed Canada's lead. Land use planning, resource utilization and territorial mapping in Africa during this period, was being run traditionally by colonial powers. The use of automated mapping systems was not a consideration. By the early 1980s many African governments were adopting information technology to varying degrees of success, as a means of achieving their development goals. This 'technological fix' was suggested by Lyon (1988) to be a particularly western based rationality, responsible for pushing developing countries towards a new form of economic colonialism. Although the use of IT may foster some sort of dependence on the developed world, the fact remains that most industry in Africa cannot function without it. There are certain IT products however which need to be appraised more carefully in terms of production and utility before their introduction to an African context is decided upon. One such product is the digital national atlas.

One of the most significant limitations to the production of digital atlases in Africa is political instability. The local news reports on Africa give the impression that a significant proportion of countries are either at war or are in a severe state of flux. On a report of the current state of affairs in Zimbabwe, it is noted that during the depths of the country's economic crisis in August 1998 the President ordered thousands of troops at great expense, to the Democratic Republic of Congo to help prevent a coup. This was at the time when a decrease in state spending was thought to be essential to the country's economy. The official reasons given for the intervention were that as part of the Southern African Development Community (SADC), Congo was entitled to receive help from neighbouring countries. Others suggest that Mugabe, "the 74-year old president was thinking of his place in history - a successful foreign policy coup would divert attention from the recent economic woes in what was once one of Africa's wealthiest

countries" (BBC,1999:6). Despite the poor economic situation, digital activity in the country appears to be on the increase. This may well be due to the fact that the British, Australian, American, Swedish, French and Norwegian governments are all financially supporting the developing national spatial data infrastructure (Matambanadzo,1997). If the national topographic database depended on the Zimbabwean government for funding, it is quite feasible that the project could come off second best in the advent of military interests taking over.

Conditions in Sierra Leone force one to question how a digital national atlas could possibly have a positive impact on the lives of the people there. A military led government was in rule for nine months in Sierra Leone's capital city. When they took power, the city was destroyed. The West African peacekeepers of ECOMOG 'freed' the city in February 1998. "The poverty, the lack of services, the perpetual power blackouts, the leaking drains, the child prostitutes - all are eloquent testament not only to seven years of insurgency but also to the decades of misrule and corruption which underlie the country's crisis" (Porteous,1999:48). It is in countries which are in this sort of state, that the idea of embarking on a digital national atlas, could be considered futile. The resources needed to re-install basic infrastructure and services are significant and every effort has to be made to meet the basic needs of the people. It will be years before the luxury of being able to focus attention on matters such as data capture for land use planning and resource utilization, become reality.

Monetary limitations, unsuitable working environments and a lack of skilled workers may destroy any hopes of digital national atlas production in African countries. These limitations are unlikely to be resolved in the near future. The only possibility for African countries like Sierra Leone to reap the benefits of digital technology may lie in foreign interests seeing a potential role for the creation of a digital database, developing and running it from outside the country. Out of the eight digital African atlases mentioned, three have resulted from personal research. There is the possibility that these atlases could be used by countries in the future as a basis from which work could be added.

It is not fair to place all African countries under the same category. There are African countries, such as

South Africa, in which the use of the digital environment for mapping and analysis has been highly successful. The country has the basic ingredients of a locally skilled workforce and good infrastructure. In a small country like Swaziland where the political environment has been fairly stable up to now, and there is interest amongst governmental and non-governmental organizations in the fostering of a digital environment, the possibility for successful adoption of digital mapping definitely exists.

There is no doubt that in the interactive environment, the use of maps is able to become more innovative. Through the overlaying of maps, a digital national atlas could well provide composite data sets depicting patterns which were never expected. It is important to keep in mind however that "Digital technology is not a panacea or great elixir. It is not a technological salvation for development." (Woods,1993:112). The output of a digital atlas is only as good as the source maps which have been used for data capture and the people who have carried out the process. If used as a data source, the inaccuracies found in the use of the 1:250 000 topographic map (1989) for example will be transferred into a digital version of the map. It is important to realise that the capabilities of these digital atlases is also limited by "the author's creative contribution" (Wood,1994:111).

Providing a means for interactive learning-by-doing in schools through the provision of a computer and CD-ROM is noble, but if the money spent on creating the atlas could be used to buy each student a paper atlas, perhaps the issue should be looked into a little more closely. Basic materials such as pencils, paper and text books are lacking in many schools in Swaziland and other African countries. Reasons for the development of a digital national atlas for an African country should be looked at carefully, perhaps carrying out a cost benefit analysis.

Whilst the potential utility of digital national atlases is easy to propose having learnt from the experiences of the developed world, their actual utility is a little more difficult to ascertain. The eight African digital atlases mentioned in this research have all been developed relatively recently, leaving little time for practical uses to have taken off. It would be interesting to know if the atlases have actually been used for land use planning, resource utilization, traffic control and disease mapping. There is no doubt that it would have been valuable to gain the opinions of the users to ascertain what functions these atlases have had.

One of the limitations of this research has been the fact that the users of these digital atlases were not contacted. This was due to time constraints and a lack of information provided by the producers.

Due to the limited number of African digital atlases available, it is difficult to make concrete conclusions about how viable their production in the African context is. From the experience of producing the *Population-Environment Atlas of Swaziland* however, it is suggested that they should not be considered a viable pursuit in countries which are unable to fulfil the guidelines set out in Chapter Five. Unfortunately the majority of African countries would probably fall into this category.

Appendices

Appendix A: Questionnaire sent to the producers of digital African atlases

I am a M.Sc Student at Rhodes University, Grahamstown. For my master's thesis, I am looking at the production and utility of digital atlases in Africa, and as part of my thesis, I am producing a digital population and environmental atlas of Swaziland. The data has been gathered from a variety of sources. The result thus far for the population section, has been population census information for the 965 enumeration areas of Swaziland (1986) to be updated for 1998 and covers relating to international, national and regional boundaries, roads, schools, tourist information, hospitals, police stations, mines and post offices. The environmental section holds elevation data, land tenure, land use, moisture and thermal zones, forested areas and reserve covers. In order to make a viable assessment of the production process and the utility of digital atlases in Africa, I thought it would be best to obtain the opinions of authors such as yourself who have produced digital atlases for African countries. I would be very grateful if you would fill out the following questionnaire.

There are four sections to this questionnaire. The first section consists of three general questions, the second section questions your experiences during the production process, the third section questions the marketability of the product and the last section relates to the utilization of these atlases in an African context.

Some of the questions may not be relevant to your experience, please do not worry about leaving these answers blank. If you feel that there is more information that the questions do not address, please feel free to include any additional information or comments you might have.

Many thanks for your time,

Section 1

What provided you with the initial impetus to produce your digital Atlas?

Did you have to acquire permission to produce the Atlas?

Who did you have to obtain permission from?

Section 2

What was the intended use of the Atlas at the start of production?

What scale base maps, orthophotos etc. did you work from?

How did you decide which scale maps you would work from?

How did you decide which covers to include?

How did you decide what level of detail would be sufficient?

What hardware and software was used?

What spatial data did you acquire?

From where did you acquire it?

Did you experience any difficulties accessing data?

Were there any conditions of use attached to the data you obtained?

Where was the Atlas produced (e.g. was any of the digitizing out-sourced?)

How many people were involved in the digitizing process?

What level of training of manpower took place?

How many hours of training did they attend and what was the cost of this?

What problems did you experience during the different stages of production (e.g. digitizing, editing)?

Did you receive funding to help finance the project?

Section 3

How much does your Atlas cost?

Do you offer any user support?

What conditions of use (if any) do you place on the users of your Atlas?

What features did you include in your atlas to make it particularly user-friendly?

How many people have bought your Atlas?

Could you provide a list of contact addresses for the people who bought or are using your Atlas?

Section 4

What potential uses do you think that digital atlases could have in Africa?

As far as you are aware, what uses have digital atlases been put to in Africa?

Any further comments:

Appendix B: A sample of the sheets indicating changes for the 1997 enumeration area identification numbers

1)

11401-11410 VICARS		11425 conf.	
11401	11402	11425	11426
11401	11402	11425	11426
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11407	11408	11431	11432
11409	11410	11433	11434
11411	11412	11435	11436
11413	11414	11437	11438
11415	11416	11439	11440
11417	11418	11441	11442
11419	11420	11443	11444
11421	11422	11445	11446
11423	11424	11447	11448
11425	11426	11449	11450
11427	11428	11451	11452
11429	11430	11453	11454
11431	11432	11455	11456
11433	11434	11457	11458
11435	11436	11459	11460
11437	11438	11461	11462
11439	11440	11463	11464
11441	11442	11465	11466
11443	11444	11467	11468
11445	11446	11469	11470
11447	11448	11471	11472
11449	11450	11473	11474
11451	11452	11475	11476
11453	11454	11477	11478
11455	11456	11479	11480
11457	11458	11481	11482
11459	11460	11483	11484
11461	11462	11485	11486
11463	11464	11487	11488
11465	11466	11489	11490
11467	11468	11491	11492
11469	11470	11493	11494
11471	11472	11495	11496
11473	11474	11497	11498
11475	11476	11499	11500
11477	11478	11501	11502
11479	11480	11503	11504
11481	11482	11505	11506
11483	11484	11507	11508
11485	11486	11509	11510
11487	11488	11511	11512
11489	11490	11513	11514
11491	11492	11515	11516
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11497	11498	11521	11522
11499	11500	11523	11524
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11523	11524	11547	11548
11525	11526	11549	11550
11527	11528	11551	11552
11529	11530	11553	11554
11531	11532	11555	11556
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11535	11536	11559	11560
11537	11538	11561	11562
11539	11540	11563	11564
11541	11542	11565	11566
11543	11544	11567	11568
11545	11546	11569	11570
11547	11548	11571	11572
11549	11550	11573	11574
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11555	11556	11579	11580
11557	11558	11581	11582
11559	11560	11583	11584
11561	11562	11585	11586
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11565	11566	11589	11590
11567	11568	11591	11592
11569	11570	11593	11594
11571	11572	11595	11596
11573	11574	11597	11598
11575	11576	11599	11600
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11579	11580	11603	11604
11581	11582	11605	11606
11583	11584	11607	11608
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11617	11618	11641	11642
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11623	11624	11647	11648
11625	11626	11649	11650
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11629	11630	11653	11654
11631	11632	11655	11656
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11635	11636	11659	11660
11637	11638	11661	11662
11639	11640	11663	11664
11641	11642	11665	11666
11643	11644	11667	11668
11645	11646	11669	11670
11647	11648	11671	11672
11649	11650	11673	11674
11651	11652	11675	11676
11653	11654	11677	11678
11655	11656	11679	11680
11657	11658	11681	11682
11659	11660	11683	11684
11661	11662	11685	11686
11663	11664	11687	11688
11665	11666	11689	11690
11667	11668	11691	11692
11669	11670	11693	11694
11671	11672	11695	11696
11673	11674	11697	11698
11675	11676	11699	11700
11677	11678	11701	11702
11679	11680	11703	11704
11681	11682	11705	11706
11683	11684	11707	11708
11685	11686	11709	11710
11687	11688	11711	11712
11689	11690	11713	11714
11691	11692	11715	11716
11693	11694	11717	11718
11695	11696	11719	11720
11697	11698	11721	11722
11699	11700	11723	11724
11701	11702	11725	11726
11703	11704	11727	11728
11705	11706	11729	11730
11707	11708	11731	11732
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11723	11724	11747	11748
11725	11726	11749	11750
11727	11728	11751	11752
11729	11730	11753	11754
11731	11732	11755	11756
11733	11734	11757	11758
11735	11736	11759	11760
11737	11738	11761	11762
11739	11740	11763	11764
11741	11742	11765	11766
11743	11744	11767	11768
11745	11746	11769	11770
11747	11748	11771	11772
11749	11750	11773	11774
11751	11752	11775	11776
11753	11754	11777	11778
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11887	11888	11911	11912
11889	11890	11913	11914
11891	11892	11915	11916
11893	11894	11917	11918
11895	11896	11919	11920
11897	11898	11921	11922
11899	11900	11923	11924
11901	11902	11925	11926
11903	11904	11927	11928
11905	11906	11929	11930
11907	11908	11931	11932
11909	11910	11933	11934
11911	11912	11935	11936
11913	11914	11937	11938
11915	11916	11939	11940
11917	11918	11941	11942
11919	11920	11943	11944
11921	11922	11945	11946
11923	11924	11947	11948
11925	11926	11949	11950
1			

2)

HACHUO		URALS	
1101-1103		11202-11242	
		11209-11233	
1101		11210-11244	
1102-1126		11211-11284	
1103-1127		11212-11235	
1104-1128		11213-11236	
1105		11214-11245	
1106-1121		11215-11246	
1107		11216	
1108-1129		11217-11247	
1109-1130		11218-11248	
1110-1131		11219	
1111-1132		11220	
1112-1133		11221-11237	
1113		11222-11238	
1114-1123		11223-11239	
1115		11224-11240	
1116		11225-11241	
1117-1124			
1118-1125		11226	
1119		11227-11242	
1120-1133		11228	
		11230	
		11231	
		11232	
Sub-TOTAL = 34		Sub Total = 47 ✓	
11201-11242		11301-11318	
1120		11301	
11202		11302	
11203		11303	
11204		11304	
11205	Part 4 11304	11305-11316	
11206	"	11306	
11207	Admin. General Part 11304	11307	

3)

43156 - 43158	43218 - 43233
43157	43219
43158	43220
43159 - 43160	43221
43160 - 43161	43222
43161 - 43162	43223 - 43239
43162 - 43163	
43163	Sub Total = 47
43164 - 43165	
43165	43301 - 43304
43166 - 43167	43301
43167 - 43168	43302 Vacant ^{Reassigned with mistake to 4/12/6}
43168 - 43169	43303
	43304
Sub Total = 116	43305 ⁴³³⁰⁶
43201 - 43240	43307
43201	43308 → 43311
43202 - 43203	43309
43203 - 43204	43310 Vacant
43204 - 43205	43311
43205 - 43206	43312
43206	43313
43207 - 43208	43314
43208	43315
43209 - 43210	43316
43210	43317
43211 - 43212	43318
43212 - 43213	43319
43213 - 43214	43320
43214 - 43215	43321 → 43322
43215	43322 → 43323 43327
43216 - 43217	43323
43217 - 43218	43324
	43325
	43326
	43327
	43328

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